Simple Rules and Problems in Navigation

SIMPLE RULES

AND

PROBLEMS

IN

NAVIGATION

BY

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TO

MR. HENRY HOWARD

DIRECTOR OF RECRUITING SERVICE

UNITED STATES SHIPPING BOARD

As a mark of appreciation of the Service rendered by him in replacing the American Flag to its proper place upon the Seas, this work is respectfully dedicated.

The Author also wishes to extend his thanks to

Capt. ROBERT J. McBRIDE,

United States Local Inspector of Hulls, New Orleans, La.

Capt. ERNEST E. B. DRAKE and WALTON B. SMITH

Instructors of Navigation in United States Shipping Board School at New Orleans, La. for their kind co-operation in compiling the information contained herein.

PREFACE

The purpose of this book is to lay before the student all the rules and problems of navigation used in every day work at sea, with short definitions of the theory of navigation, and other useful information that the young officer should know.

The International Rules of the Road are not given, as they can be obtained free of cost on application to any Board of Local Inspectors of Steam Vessels.

In making up the rules for working the problems, the author may have repeated himself several times, but it has been his experience in teaching navigation that this is necessary to make the student understand.

All of the various problems are worked out in full, with no attempt to save figures or cut down the working in any way. It is recommended to the beginner that he names every thing as he goes along in his problems, as it will help to memorize.

One of the greatest faults with navigators of to-day is their tendency to try and cut down figures in their problems. There is no excuse for this, as a man at sea has plenty of time to work his problems, and it has been this tendency for rule of thumb methods that has been the loss of many a ship. It is time enough to learn the short methods after you know the proper way, and have had several years of practical experience.

There are many excellent books on the theory of navigation, but very few that the ordinary man can understand, and this book has been published with theory eliminated entirely.

The books used in working the different problems are Bowditch's American Practical Navigator, American Line of Position Tables, American Azimuth Tables and 1918 American Nautical Almanac.

It is intended that this book shall be kept up to date, and the answers of the different problems for the coming years will be published in pamphlet form, and can be obtained by addressing the author enclosing 25 cents.

It is hoped that this book will be a help to the reader, as the author has tried to make it in as plain language as possible.

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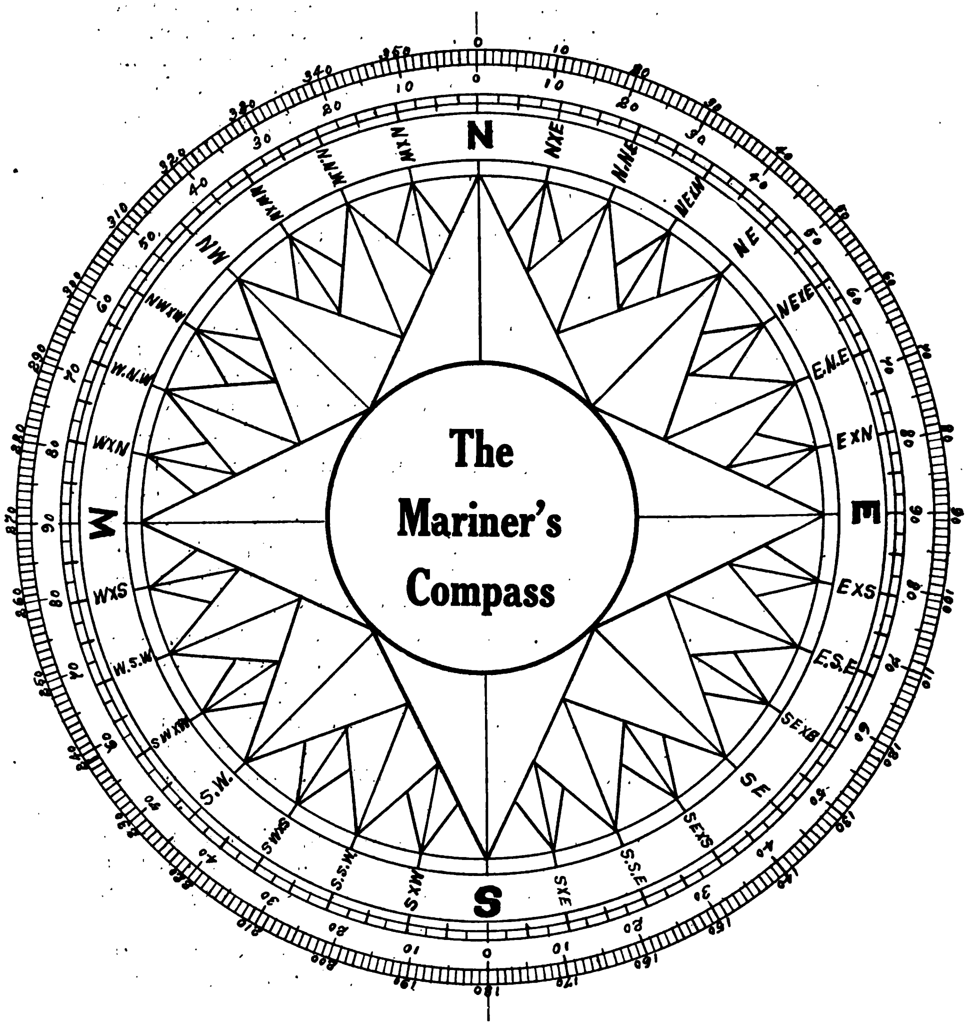


TABLE FOR CONVERTING POINTS OF COMPASS INTO DEGREES.

As the Ship's Course is usually expressed in degrees, the following table will be found useful for reference.

NORTH TO EAST	NORTH TO WEST	SOUTH TO EAST	SOUTH TO WEST	POINTS	D.	M.	S.
North	North	South	South	0	0°	0	0
N ¼ E	N ¼ W	S ¼ E	S ¼ W	¼	2°	48′	45″
N ½ E	N ½ W	S ½ E	S ½ W	½	5°	37′	30″
N ¾ E	N ¾ W	S ¾ E	S ¾ W	¾	8°	26′	15″
N by E	N by W	S by E	S by W	1	11°	15′	00″
N by E ¼ E	N by W ¼ W	S by E ¼ E	S by W ¼ W	1¼	14°	3′	45″
N by E ½ E	N by W ½ W	S by E ½ E	S by W ½ W	1½	16°	52′	30″
N by E ¾ E	N by W ¾ W	S by E ¾ E	S by W ¾ W	1¾	19°	41′	15″
N N E	N N W	S S E	S S W	2	22°	30′	00″
N N E ¼ E	N N W ¼ W	S S E ¼ E	S S W ¼ W	2¼	25°	18′	45″
N N E ½ E	N N W ½ W	S S E ½ E	S S W ½ W	2½	28°	7′	30″
N N E ¾ E	N N W ¾ W	S S E ¾ E	S S W ¾ W	2¾	30°	56′	15″
N E by N	N W by N	S E by S	S W by S	3	33°	45′	00″
N E ¾ N	N W ¾ N	S E ¾ S	S W ¾ S	3¼	36°	33′	45″
N E ½ N	N W ½ N	S E ½ S	S W ½ S	3½	39°	22′	30″
N E ¼ N	N W ¼ N	S E ¼ S	S W ¼ S	3¾	42°	11′	15″
N E	N W	S E	S W	4	45°	00′	00″
N E ¼ E	N W ¼ W	S E ¼ E	S W ¼ W	4¼	47°	48′	45″
N E ½ E	N W ½ W	S E ½ E	S W ½ W	4½	50°	37′	30″
N E ¾ E	N W ¾ W	S E ¾ E	S W ¾ W	4¾	53°	26′	15″
N E by E	N W by W	S E by E	S W by W	5	56°	15′	00″
N E by E ¼ E	N W by W ¼ W	S E by E ¼ E	S W by W ¼ W	5¼	59°	3′	45″
N E by E ½ E	N W by W ½ W	S E by E ½ E	S W by W ½ W	5½	61°	52′	30″
N E by E ¾ E	N W by W ¾ W	S E by E ¾ E	S W by W ¾ W	5¾	64°	41′	15″
E N E	W N W	E S E	W S W	6	67°	30′	00′
E N E ¼ E	W N W ¼ W	E S E ¼ E	W S W ¼ W	6¼	70°	18′	45″
E N E ½ E	W N W ½ W	E S E ¾ E	W S W ½ W	6½	73°	7′	30″
E N E ¾ E	W N W ¾ W	E S E ½ E	W S W ¾ W	6¾	75°	56′	15″
E by N	W by N	E by S	W by S	7	78°	45′	00″
E ¾ N	W ¾ N	E ¾ S	W ¾ S	7¼	81°	33′	45″
E ½ N	W ½ N	E ½ S	W ½ S	7½	84°	22′	30″
E ¼ N	W ¼ N	E ¼ S	W ¼ S	7¾	87°	11′	15″
East	West	East	West	8	90°	00′	00″

USEFUL DEFINITIONS

AND

INFORMATION

CHAPTER I.

ALTITUDE: The angular height of a heavenly body above the horizon.

AMPLITUDE: The bearing (never exceeding 90 degrees) of a heavenly body at rising or setting.

APPARENT TIME: Time calculated by the sun. When the sun crosses the meridian of the observer it is apparent noon where he is, as well as at all places on his meridian from pole to pole.

ASTRONOMICAL TIME: This commences at noon of the civil day, the hours being counted numerically from 1 to 24, so that the day begins and ends at noon. To convert civil time into astronomical time proceed as follows: If the civil time is A. M. take 1 from the date and add 12 to the hours. If P. M. take away the sign P. M. and the answer will be Astronomical Time.

AZIMUTH: The bearing (never exceeding 180 degrees) of a heavenly body calculated from the north and south points of the heavens.

CHRONOMETER: A marine time piece constructed with the idea of great accuracy, and set to the time of some first meridian. The Americans and English use the time of the meridian of Greenwich.

CIVIL TIME: The civil time consists of 24 hours; it commences at midnight and the first 12 hours are called A. M. and the second 12 hours P. M.

COMPASS: The mariner's compass consists of a magnetized steel bar secured parallel to the north and south line of a circular card, which latter is balanced on a pivot so as to turn freely in the horizontal plane, and to indicate the magnetic meridian. The surface of the card is divided into thirty-two courses with their intermediate quarters, and in addition to this all steamships have the circumference of the compass card graduated into degrees.

VARIATION OF THE COMPASS: The compass needle when uninfluenced by deviation points to the magnetic poles of the earth, and as these do not coincide with the true or geographical poles, the magnetic meridians form an angle with the true meridians, and this is called the variation of the compass, which varies in extent in different parts of the world. The magnetic North pole is situated in Latitude 70° North, Longitude 97° West. The magnetic South Pole is situated in Latitude 70° South, Longitude 145° East. The variation of the compass is not constant, but undergoes an annual change, and the amount of this yearly increase or decrease will be found plainly marked on charts.

DECLINATION: The angular distance of a heavenly body North or South of the celestial equator.

DEPARTURE: The amount of easting or westing made by a vessel from a certain point in miles.

DEVIATION OF THE COMPASS: What is known as the deviation of the compass is the deflection of the compass needle from the magnetic meridian caused by by the attraction of the hull, machinery, smokestacks, masts, or by certain elements of magnetism in the cargo. The manner of ascertaining the existence and amount of compass deviation is found by taking bearings of the sun or some fixed object. Deviation is named East or West according as to the North point of the compass is drawn to the eastward or westward of the magnetic meridian.

EQUATION OF TIME: The difference between mean and apparent time.

LATITUDE: The distance of a place on the earth's surface North or South of the equator, expressed in degrees, minutes and seconds.

LONGITUDE: The distance of a place on the earth's surface East or West of some given prime meridian, expressed in degrees, minutes and seconds.

LONGITUDE IN TIME: The position or distance of a vessel east or west of a given prime meridian, expressed in hours, minutes and seconds.

MAGNETIC BEARING: A bearing according to the compass or the direction pointed out by the magnetic meridian.

MEAN NOON: The time that the mean sun is supposed to cross the meridian of the observer.

MEAN SUN: An imaginary sun which is supposed to move uniformly, and to cross the same meridian at the same time every day, thus giving a value of exactly 24 hours to the day. This mean or fictitious sun sometimes crosses the observers meridian a little in advance of the true sun, and other times a little after it, and this difference or interval between the real and imaginary suns is known as the equation of time.

MEAN TIME: Time calculated by the motion of the mean sun. All watches and clocks represent mean time.

MERCATORS SAILING: A method of finding the true course and distance between two places by employing meridional parts instead of the middle latitude.

MERIDIAN: The highest point reached by a heavenly body from its rising to its setting.

MERIDIAN ALTITUDE: The angular height of a heavenly body from the horizon line at the time the body is crossing the meridian.

MIDDLE LATITUDE SAILING: The method of finding the true course and distance between two places by employing the middle latitude between them.

PARALLAX: Is the correction applied to observed altitude of sun, caused by observing the sun from earth's surface instead of centre.

PARALLEL SAILING: Sailing on a parallel; sailing true east or west.

PELORUS: An instrument much used for observing bearings and for finding the deviation of the compass. It is a dummy compass with sight vanes attached.

POLAR DISTANCE: The angular distance of a heavenly body from the pole nearest the observer.

REFRACTION: The change of direction of a ray of light in passing through atmospheric mediums of varying density.

SEMI-DIAMETER: Half a diameter, or the distance from top or bottom of the sun to the centre.

SEXTANT: An instrument of reflection used by navigators for measuring the altitudes of heavenly bodies.

SEXTANT ADJUSTMENTS: No. 1 TO ADJUST THE INDEX GLASS: This glass must be perpendicular to the plane of the instrument. To prove this, set the vernier to about the centre of the arc and clamp it. Hold the instrument face up with the arc away from you, then look obliquely into the index glass and observe if the arc seen direct and its reflection form one continuous line; if so, the glass is perpendicular to the plane of the instrument, but if the reflected image appears to be lower than the other it proves the glass leans backward; if, however, the reflected image appears to be higher the glass leans forward.

No. 2. ADJUSTMENT OF THE HORIZON GLASS: This glass must be also perpendicular to the plane of the instrument. To test this, let the two zeros cut, and holding the instrument almost horizontal look at the horizon line, and note if the direct and the reflected images of the horizon line coincide—that is, if they show as an unbroken line both in the silvered and clear parts of the glass. If they do, the horizon glass is perpendicular, but if they do not, then adjust the glass to the required angle by the adjusting screw on back.

No. 3. THE TWO GLASSES TO BE PARALLEL: With the two zeros cutting, hold the instrument vertically, and if the direct and reflected images of the horizon line show as an unbroken line the horizon glass is parallel to the index glass, but if they do not show in an unbroken line, adjust the horizon glass by the adjusting screw on back.

No. 4. TO FIND THE INDEX ERROR: Should it prove impossible to obtain a perfect adjustment, find the error of the instrument as follows: Let the two zeros cut, then holding the instrument vertically look at the horizon, and gently finger the tangent screw so as to move the vernier either forward or backward along the arc until the image of, and the horizon line itself show in an unbroken line across the glass, then the difference between zero on the vernier and zero on the arc will be the index error.

SIDERIAL TIME: Time measured by the stars. Siderial time commences when the First Point of Aries is on the meridian, and is counted from 1 to 24 hours, when the same point returns to the meridian again.

SOLAR TIME: Time measured by the sun.

VARIATION: The divergence of the compass needle from the true North.

ZENITH DISTANCE: The angular distance of a heavenly body from the zenith of the observer.

ZENITH: That point in the heavens directly overhead of the observer, and 90 degrees distance from every point of the horizon.

PRIME VERTICAL: A heavenly body is on the prime vertical when it bears true East or West, and is the best time to observe a sight for longitude, as an error of latitude will have no effect on the longitude.

RIGHT ASCENSION: The distance in time of a heavenly body reckoned eastward on the equinoctial from the First Point of Aries.

FIRST POINT OF ARIES: That point in the heavens which the sun's centre occupies when its declination changes from North to South, or when the sun crosses the line bound North.

MERCATOR CHART: The Mercator chart has a compass printed on it, with an arrow to represent the North point which is the top, the bottom South; East right, West left. Meridians are the lines running North and South, on the chart—those on the sides, are divided into degrees and minutes, and are called Graduated Meridians. Parallels of latitude are the lines running east and west—those at top and bottom are divided into degrees and minutes, and are called Graduated Parallels. Latitude is measured at the sides on the graduated meridians. Longitude is measured at the top and bottom on the Graduated Parallels. A Mercator chart is a distortion of the earth's surface, the meridians being equal, and the parallels increased from the equator to the poles. The outer compass is a true compass, and the inner compass is a magnetic compass. The variation is found printed on the compass, and also lines of variation will be found on chart. Soundings are given in fathoms in clear parts, and in feet in shaded parts, and the nature of bottom is given by letters abbreviated. The chart gives all information as to light ships, lighthouses, visibility of lights, and nature of lights.

CLINOMETER: An instrument used for registering amount of list or heel, generally to be found on the binnacle. As one degree of list will frequently alter the deviation to a like amount, this will require careful watching.

It also comes in handy when putting ship in dry dock to ascertain if ship is upright.

HYDROMETER: An instrument used for measuring the density or the specific gravity of liquids, used by seamen for finding the different drafts that a ship will float at, in fresh and salt water. The specific gravity of fresh water is 1000. The specific gravity of salt water is 1026. To find the draft a ship can be loaded to in fresh water, in order to ascertain the amount of water she will draw at sea, proceed as follows: Take the density of water at wharf, from below the surface if possible, by hydrometer. Multiply mean draft of ship by this reading, and divide by 1026. The result will be mean sea draft. (By mean sea draft is meant, adding forward and after draft together, and dividing sum by 2.) For example: Dock water reading of hydrometer 1006. Mean draft of vessel 21 ft.

$$\frac{1006 \times 21}{1026} = 20.6' \text{ Mean sea draft.}$$

MERCURIAL BAROMETER: The barometer is an instrument used for determining at any moment the weight or pressure of the atmosphere in its immediate vicinity. It is made by taking a glass tube sealed at one end, and placing the other end in a receptacle containing mercury. The mercury will then descend the tube until the weight of the column of mercury in the tube is balanced by the atmospheric pressure or weight on the mercury in the cup. The glass tube is graduated in proper ratio, so that the increase or decrease of pressure can be read on the scale at the side of the glass.

ANEROID BAROMETER: Is another type of barometer, which owing to its compact form, and the fact that no liquid is used, is coming into use more and more for sea service. The varying pressure of the atmosphere is registered on the dial by a hand, which is controlled by the expansion or contraction of a metal box, generally of a circular form with corrugated surface, from which almost all air has been withdrawn leaving a partial vacuum.

The instruments should not be removed from the ship, but frequent comparisons should be made to ascertain error of instrument by reading barometer at 12 hour intervals 3 times (8 A. M. or Noon preferable) and forwarding same to Local Weather Bureau.

TO FIND THE STORM CENTRE OF TROPICAL CYCLONIC STORMS: In the Northern Hemisphere look into wind and 8 points to the right will be the centre. In the Southern Hemisphere 8 points to the left will be centre approximately.

NOTICES TO BE POSTED ON STEAMERS CARRY ING PASSENGERS: Certificate of Inspection, 2 Copies of Pilot Rules, 2 Copies of Safety First, 3 Copies Excluding Certain Persons from Pilot House, 3 Copies of Station bills required, 5 Copies of Line Carrying Gun Drill, Station Bills for Fire and Boat Drills for Deck and Engineer's Department, Life Preserver Notices to be posted in each stateroom and in conspicuous places around vessel. Also to have on board 2 Copies of Law Governing the Steamboat Inspection Service, and 1 Copy of General Rules and Regulations of the Board of Supervising Inspectors.

DANGEROUS ARTICLES FORBIDDEN ON PASSENGER STEAMERS: No loose hay, loose cotton, or loose hemp, camphene, nitroglycerine, naptha, benzine, coal oil, crude or refined petroleum, benzole, or other like explosive burning fluids, or like dangerous articles, shall be carried as freight or used as stores on any steamer carrying passengers. Gunpowder may be carried if the vessel is provided with a chest or safe composed of metal, or entirely lined or sheathed therewith, at a secure distance from any fire, after an examination has been made by the Local Inspectors of such chest or safe, and a license to carry gunpowder has been issued, such license to be kept conspicuously posted on board vessel.

WATCHMEN REQUIRED ON PASSENGER STEAMERS: Every steamer carrying passengers during the night time shall keep a suitable number of watchmen in the cabins, and on each deck to guard against fire or other dangers, and to give alarm in case of accident or disaster. All steamers while navigating at night shall keep a man on the lookout forward if weather permits, or at some other suitable place.

REPORTS TO BE MADE TO LOCAL INSPECTORS: The Master of every steamer shall make a report in writing to the Local Inspectors of any accident to vessel or loss of life. Notice shall be made in writing to Local Inspectors of number of passengers carried, and fire and boat drill practiced, each month.

DRILLS TO BE ENTERED IN LOG BOOK: Fire and boat drills shall be practiced once each week on

passenger steamers. The line carrying gun shall be fired once every three months, and such drills shall be entered in ship's log book.

HOW FIRE HOSE SHALL BE CARRIED: Fire hose shall be carried connected to fire plugs, and ready for immediate use, with suitable spanners at each plug.

LAMP AND PAINT LOCKER REQUIREMENTS: All steamers carrying passengers shall have a metal lined paint and lamp locker. This locker to have a ¾″ steam pipe run into it for smothering fires, and the valve of such steam pipe shall be plainly marked.

HOW LIFE BOATS SHALL BE CARRIED AND MARKED: All lifeboats on steamers carrying passengers shall be carried under davits of approved mechanical design, capable of sustaining the weight of boat and equipment and number of persons allowed to be carried. They shall be marked in numerical order, odd numbers on starboard side, even numbers on port side, cubical contents and number of persons allowed shall be painted on each bow in letters not less than ¾″ high. Vessel's name and home port shall be painted on stern in letters 3″ high. Number of persons allowed shall be painted on two thwarts in letters 3″ high. All boats shall be in condition for immediate launching at all times and the falls shall not be painted or covered, and shall be stowed in covered tubs or reels on outside of boat.

EQUIPMENT OF LIFEBOATS: A properly secured life line the entire length on each side, such line to be festooned in bights not longer than 3 feet, with a seine float in each bight; at least 2 life preservers; 1 painter of not less than 2¾″ manila rope; a full complement of oars and 2 spare oars; a set and a half of rowlocks, each rowlock to be attached to boat with a separate chain; 1 steering oar with rowlock or becket, or 1 rudder with yoke and suitable yoke ropes; 1 boat hook attached to staff of a suitable length; 2 axes; 1 bucket with lanyard attached; 1 bailer; 1 liquid compass with not less than 2″ card; 1 lantern with attached lamp containing sufficient oil to burn at least nine hours and ready for immediate use; 1 gallon of illuminating oil in a substantial can; at least one box of friction matches wrapped in a waterproof package, and carried in a box attached to the underside of the stern thwart; at least 2 quarts of water for each person carried, in a strong wooden breaker or suitable tank fitted with a

siphon, pump, or spigot for drawing water; 2 drinking cups of enameled metal; 1 substantial metal can containing 2 lbs. of hard bread for each person carried, the metal bread can to be fitted with an opening in the top not less than 5″ in diameter, properly protected with a screw cap of heavy cast brass with machine thread and an attached double toggle seating to a pliable rubber gasket which shall insure a tight joint in order to properly protect the contents of the can; 1 canvas bag containing sailmaker's palm and needles, sail twine, marline spike, and hatchet; 12 pyrotechnic red lights carried in a metal case; 1 drag sail; 1 gallon of storm oil; and 1 mast and sail with necessary rigging.

EQUIPMENT OF LIFE RAFTS: A properly secured life line entirely around the sides and ends of raft festooned to the gunwales in bights not longer than 3 feet with a seine float in each bight; 1 painter of 2¾″ manila rope of a suitable length; 4 oars; 5 rowlocks properly attached; 1 boat hook attached to staff of suitable length; 1 self-igniting life-buoy light; 1 sea anchor; 1 vessel containing 1 gallon of vegetable or animal oil, so constructed that the oil can be easily distributed on the water, and so arranged that it can be attached to the sea anchor; 2 lbs. of hard bread for each person carried, carried in a receptacle same as in lifeboats; 1 water breaker containing 1 quart of water for each person carried; 2 enameled drinking cups; 1 metal case containing 6 pyrotechnic red lights; 1 water tight box of matches. All loose equipment must be securely attached to the raft to which it belongs.

HOW TO MARK A LEAD LINE: 2 fathoms 2 strips of leather; 3 fathoms 3 strips of leather; 5 fathoms white rag; 7 fathoms red rag; 10 fathoms leather with 1 hole; 13 fathoms blue rag; 15 fathoms white rag; 17 fathoms red rag; 20 fathoms leather with 2 holes; 25 fathoms cord with 1 knot; 30 fathoms cord with 3 knots.

EXPLAIN THE USE OF THE DEEP SEA SOUNDING MACHINE: The deep sea sounding machine has a reel of fine wire to which the lead is attached by a line having made fast to it the lead and a brass tube. Into the brass tube is placed the depth recorder which is a long glass tube, which is placed sealed end up. When the lead is armed and everything is ready the brake is released, and the wire is allowed to run out until the bottom is struck. The amount of wire run out is shown by an indicator on the side of the machine. The amount of wire is not the depth of water

obtained, as the amount run out varies with the speed of the ship. The wire is then reeled back, and the glass tube is taken out. The pressure of the water causes the tube to become discolored a certain length up for a certain depth, and the amount of such depth is found by measuring the discoloration on a scale provided for that purpose.

HOW TO FIND COURSE AND DISTANCE BY CHART AND PARALLEL RULES: Lay the parallel rules on the two places that the course and distance is wanted for. After obtaining proper angle, move the rules to the nearest compass rose on the chart and read off the course obtained. Measure the distance between the places on the side of the chart in the latitude column always, using the middle latitude between the places.

HOW TO FIND SHIP'S POSITION BY CROSS BEARINGS: Take a bearing of two fixed objects by ship's compass, and correct for the deviation for ship's head and the variation at the place, making the bearings true. Lay off the bearings on the chart from the objects used, and where the two lines cross one another will be the ship's position at time of taking the bearings.

HOW TO FIND THE DISTANCE OFF A FIXED POINT BY FOUR POINT BEARINGS: Take a bearing of the object when it bears four points on the bow and also when abeam. If the ship has held the same course while taking the two bearings the distance run between the two bearings will be the distance off the object when abeam.

WHAT IS THE DUTY OF A MATE ON WATCH: Keep a good lookout, watch the steering, see that man on lookout keeps a good lookout. If it comes on thick or foggy, stop or slow the vessel, blow the whistle, and send someone to call the Master.

WHAT WOULD YOU DO SHOULD A MAN FALL OVERBOARD? Stop the ship, throw the stern of the ship from the man, send a man aloft to watch out and direct the boat, throw over a life buoy, and lower the lee boat.

WHAT WOULD YOU LOOK AFTER WHEN LOWERING A BOAT, AND HOW WOULD YOU PLACE YOUR MEN IN THE BOAT? See if the plug was in the boat, and the davit falls all clear. Place one man in bow and another in stern to unhook davit tackles, rest of crew sitting down ready with oars.

HOW WOULD YOU HANDLE A BOAT IN A HEAVY SURF? I would head my boat to the sea and pull towards it when it breaks. If about to beach a boat in the surf pull in close to the breakers, then back the boat in, pulling toward the sea as it breaks. Do not let her fall broadside too, or the boat will swamp.

YOUR SHIP IS ASHORE, YOUR BOATS AND LIFE RAFTS ARE ALL STOVE IN, WHAT WOULD YOU DO TO SAVE THE PEOPLE ON BOARD YOUR VESSEL? Send up distress rockets and make distress signals to attract the attention of the life saving crew on shore. If not answered, build a raft out of anything that will float, bend a line to it, and throw the raft overboard and see if it will drift ashore. If so, haul it back again and put two good swimmers and a long line coiled on the raft, and then let it drift as near the shore as it will go, then let the men jump over and swim ashore with the line. Then haul the raft backward and forward until every one is off the vessel.

HOW WOULD YOU FIND THE APPROXIMATE POSITION OF A VESSEL, BY TAKING ONE BEARING OF A POINT OR LIGHT? Take a bearing of the point, and drop the lead. Then go to the chart and draw a line representing the bearing of the particular point, and hunt along this line until the depth of water and nature of bottom is found. The result will be the approximate position of the vessel.

IN CASE OF COLLISION WHILE IN COMMAND OR IN CHARGE OF A WATCH WHAT ARE YOUR DUTIES? Stop the ship and ascertain the damage to my own vessel. Call all hands to attention, serve out life belts, man boats and get ready for lowering. Next ascertain if the other vessel needs assistance; if so, render it, if not, and both vessels are able to proceed, exchange names of vessels and port of registry, and immediately upon arrival in port send in a written report to the steamboat inspectors, and make out wreck report and file it at the custom house. If the report is not made the Master is liable to a fine.

WHAT ARE THE DUTIES OF A MATE TOWARDS THE MASTER, PASSENGERS AND CREW? The duty of an officer of a vessel is to obey all orders emanating from his superior officer; assist in the navigation of the vessel to the best of his ability; report to the Master whenever the officer is of the opinion that a danger exists if the orders of his superiors are carried out, show an example

to the crew by obeying all orders promptly; keep the passengers out of dangerous places; see that the crew know their stations in case of fire or collision; do not molest passengers; see that all life saving and fire fighting equipment is kept ready for use and in good condition; and keep a good lookout while on watch.

WHAT DO THE FIGURES AND LETTERS YOU SEE ON A CHART REPRESENT? The figures represent the depth of the water in fathoms or feet, at a mean low water, and the letters represent the nature of the bottom.

IF YOU THINK YOU HEAR A FOG WHISTLE ON YOUR BOW, WHAT WOULD YOU DO? Stop my vessel, ascertain the position of the other vessel if possible, and then proceed with caution.

HOW WOULD YOU APPROACH A SINKING VESSEL WITH A BOAT IN A HEAVY SEA AND TAKE THE PEOPLE OFF, IF IT WAS TOO ROUGH TO GO ALONGSIDE? Run dead to windward of the sinking vessel as close as safety will permit; stop my ship and make one side of my ship a lee side, lower away the lee boat, and at the same time throw overboard a can of oil to smooth the sea. Let the boat drift down toward the wreck, and when the boat is near the wreck, look out for wreckage and fall in on the lee side of the wreck as near as possible. If dangerous to go alongside, throw the boat head up and let a man stand in the bow of the boat and throw a heaving line with a bowline in the end of it on board the wreck, which one of the people on board will place around him, and then jump overboard, and who will be hauled into the boat. The vessel in the meantime will run to the leeward and wait for the boat, when she leaves the wreck with a boat load of people. This will be repeated until everybody is off the wreck.

HOW WOULD YOU HEAVE TOO IN A GALE, UNDER STEAM, OR WITH ENGINES DISABLED? Slow the engines, head her up to the sea, and get on some after canvas. If she will not lay too, use a drag over the weather bow. If disabled try to make her lay her head to the sea with a drag over her bow, and some after canvas, but if she would not lay too keep her helm amidship, take in the after canvas and pass the drag aft to the weather quarter and let her lay stern too.

HOW WOULD YOU APPROACH THE LAND IN A FOG, AND WHAT PRECAUTION WOULD YOU TAKE? Go slow and use the lead frequently. If in doubt stop and wait for weather to clear.

WHEN TAKING SOUNDINGS, WHAT DO YOU USE BESIDES THE DEPTH OF WATER TO CONFIRM YOUR POSITION? The nature of the bottom which is brought up on the arming of the lead.

BUOYAGE SYSTEM OF U. S. On entering channels nun shaped or peaked buoys, red with even numbers, starboard side. Can shaped or flat top buoys, black with odd numbers, port side. Black and white perpendicular striped buoys are fairway buoys. Black and red horizontal striped buoys are obstruction buoys, give berth on both sides. White buoys are anchorage ground, anchor inside of buoys. Gas, Bell and Whistling Buoys are colored and placed according to the needs of surrounding and locality and are described in local buoy books. Buoys and beacons with cages are generally placed at turns in narrow channels, and may be colored with reference to background.

DANGER BEARING: If crossing a vessel or approaching the land observe a bearing. If this bearing does not change, risk of collision or grounding should be assumed.

U. S. WEATHER BUREAU SIGNALS.

THE SMALL CRAFT WARNING: A red pennant displayed alone indicates that, while the wind may not reach a velocity sufficiently high to justify the display of a regular storm warning, they will interfere with the safe operation of small craft, such as those engaged in fishing, towing, motor-boating, and yachting.

THE STORM WARNING: A red flag (8 feet square) with black centre (3 feet square) indicates that a storm of marked violence is expected.

PENNANTS: The pennants displayed with the flag indicates the direction from which the wind is expected to blow.

THE RED PENNANT: (8 feet hoist and 15 feet fly) displayed with the flag indicates easterly winds.

THE WHITE PENNANT: (8 feet hoist and 15 feet fly) displayed with the flag indicates westerly winds.

When the RED PENNANT is hoisted above the storm flag, winds are expected from the NORTHEAST QUADRANT; when below, from the SOUTHEAST QUADRANT.

When the WHITE PENNANT is hoisted above the storm flag, winds are expected from the NORTHWEST QUADRANT: when below, from the SOUTHWEST QUADRANT.

NIGHT WARNINGS: By night a red light indicates easterly winds; and a white light below a red light, westerly winds.

THE HURRICANE WARNING: Two storm flags (red with black centre), displayed one above the other, are used to announce the expected approach of tropical hurricanes, and also of those extremely severe and dangerous storms which occasionally move across the Lakes and the northern Atlantic coast.

Neither small craft nor hurricane warnings are displayed at night.

INSTRUCTIONS FOR THE USE OF THE GUN AND ROCKET APPARATUS, AS PRACTICED BY U. S. LIFE SAVING SERVICE.

If your vessel is stranded and a shot with a small line is fired over it, get hold of the line, haul it on board until you get a tail block with an endless line rove through it, make the tail block fast to the lower mast well up, or in the event the masts have gone, to the best place to be found. Cast off small shot line, see that rope in block runs free, and make signal to shore.

A hawser will be bent to the endless line on shore, and hauled off to your ship by the life saving crew. Make hawser fast about two feet above the tail block, and unbend hawser from endless line. See that rope in block runs free, and make signals to shore.

Life savers on shore will then set hawser taut, and by means of the endless line haul off to your ship a breeches buoy.

Let one man get clear into the breeches buoy, thrusting his legs through the breeches, make signal to shore as before, and he will be hauled ashore by the life savers, and the empty buoy returned to the ship.

The following signals have been adopted by the Coast Guard of the United States:

No. 1. Upon the discovery of a wreck by night the station crew will burn a red pyrotechnic light or a red rocket to signify, "You are seen; assistance will be given as soon as possible."

No. 2. A red flag waved on shore by day, or a red light, red rocket, or red roman candle displayed by night, will signify, "Haul away."

No. 3. A white flag waved on shore by day, or a white light swung slowly back and forth, or a white rocket or white roman candle fired by night, will signify, "Slack away."

No. 4. Two flags, a white and a red, waved at the same time on shore by day, or two lights, a white and a red, slowly swung at the same time, or a blue pyrotechnic light burned by night, will signify, "Do not attempt to land in your own boats; it is impossible."

No. 5. A man on shore beckoning by day, or two torches burning near together by night, will signify. "This is the best place to land."

INTERNATIONAL CODE OF SIGNALS.

The International Code of Signals consists of 26 Flags—one for each letter of the alphabet—and a Code Flag.

Letters "A" and "B" are Burgees.

Letters "C," "D," "E," "F" and "G" and "Answering Pennant" are PENNANTS.

The balance of the alphabet are in square flags.

TWO FLAG SIGNALS: Are urgent and important signals. Such as "NC" which means "I am in distress."

THREE FLAG SIGNALS: Are general signals. Such as "CXL" which means "Do not abandon me."

FOUR FLAG SIGNALS: Are Geographical, Alphabetical Spelling Tables, and Vessels' Numbers. Such as "AZOT" is the Geographical Signal for New York City. Alphabetical signals are the words spelled out by the flags, and answered by the Answering Pennant. Vessels' Numbers are given in the List of Merchant Vessels. Each vessel having a certain number.

Meanings of Flags and Pennants Hoisted Singly.

"B" I am taking in (or, discharging) explosives.

"C" Yes, or, Affirmative.

"D" No, or, Negative.

"L" I have (or, have had) some dangerous infectious disease on board.

"P" I am about to sail; all persons to report on board.

"Q" I have a clean bill of health, but am liable to quarantine.

"S" I want a pilot.

How to Make a Signal.

1. Ship A, wishing to make a signal, hoists her Ensign code flag under it.

2. When Ship A has been answered by the vessel she is addressing she proceeds with the signal which she desires to make, first hauling down her code flag if it is required for making the signal.

3. Each hoist should be kept flying until ship B hoists her Answering Pennant.

4. When ship A has finished signalling she hauls down her Ensign.

How to Answer a Signal.

1. Ship B (the ship signalled to) on seeing the signal made by ship A, hoists her Answering Pennant at the "Dip."

2. When A's hoist has been taken in, looked out in the signal book, and is understood, B hoists her Answering Pennant "Close Up" and keeps it there until A hauls her hoist down.

3. B then lowers her Answering Pennant to the "Dip" and waits for next hoist.

4. If the flags in A's hoist cannot be made out, B keeps her Answering Pennant at the "Dip" and hoists the signal OWL or WCX, or such other signal as may meet the case; and when A has repeated or rectified her signal, and B thoroughly understands it, B hoists her Answering Pennant "Close Up."

DOT AND DASH CODE.

This method is used to converse with vessels at sea by means of flashlights, flags, or whistle.

With a little practice the reader will have no trouble in being proficient.

Alphabet.

A	.—	N	—.
B	—...	O	———
C	—.—.	P	.——.
D	—..	Q	——.—
E	.	R	.—.
F	..—.	S	...
G	——.	T	—
H	....	U	..—
I	..	V	...—
J	.———	W	.——
K	—.—	X	—..—
L	.—..	Y	—.——
M	——	Z	——..

Numerals.

1	.————	6	—....
2	..———	7	——...
3	...——	8	———..
4	....—	9	————.
5	.....	0	—————

Additional Symbols.

Cornet —————

Letters (follow) ————.

Signals (follow) ..——

Code Interval or Designator .—.—

Conventional Signals.

End of word	Interval
End of sentence	Double Interval
End of message	Triple Interval
Signal separating preamble from address; address from text; text from signature	—...—
Acknowledgement	.—. (R)
Error	....
Interrogatory	..——..
Repeat after (word)	Interrogatory, A (word)
Repeat last word	Interrogatory twice

Repeat message	Interrogatory three times
Send faster	QRQ
Send slower	QRS
Cease sending	QRT
Wait a moment	. — . . .
Execute	IX, IX
Move to your right	MR
Move to your left	ML
Move up	MU
Move down	MD
Finished (end of work)	. . . — . —

SIMPLE RULES FOR STOWAGE OF CARGO.

When the cargo is discharged from the ship all the holds and tween decks, should be well cleaned and dunnage stacked up on the side ready for next cargo.

Dunnage is loose wood, laid on the bottom and tween deck of a vessel to prevent damage by vessel leaking, leaky water pipes, liquid cargo leaking, etc.

Dunnage should be laid in the holds fore and aft about 9 inches high, and in the tween deck athwartship about 3 inches high. The reasons for laying dunnage in this way is to allow any water that may get under the cargo to have free access to bilge suctions, and scupper pipes.

Casks are stowed fore and aft, bung up, and bilge free, with dunnage under the quarters, and well chocked off. Begin amidship for first tier, and work towards the wings.

To determine the location of the bung of a cask if it is not visible look for the rivets in the hoops, which will always be in line with the bung.

Bale goods should be stowed on their flat, with marks and numbers up.

Acids should be stowed on deck, so that it can readily be thrown overboard in case of leakage, and should be securely lashed.

When carrying a cargo of cotton special attention should be given that dunnage is well laid, and all iron work in holds properly protected, so that no friction may occur between the bands of the bales and the iron work.

A cargo of coal should be taken on board dry, and plenty of surface ventilation given to holds to avoid against the coals getting heated and taking fire. In fine weather at sea the hatches should be left open, and the temperature of the holds taken each watch. In case of fire batten down all hatches, ventilators, etc., and turn steam in holds, it is possible in some instances to hold the fire in this way.

On taking on board a cargo of steel rails operations should begin in the main hold, and the iron stowed fore and aft until level with keelson, then stowed grating fashion. To protect the sides of the vessel, place rails fore and aft, and also have locking tiers of rails; when high enough lash all together with chains, and place battens across and tom all down securely from beams; also tom from the sides of the vessel.

A cargo of iron should be stowed in the body of the vessel, trimmed towards the wings, and raised up in the holds to a good height; by doing so the vessel will be in better trim for rough weather, and will not roll so heavily.

For general cargo have all the holds cleaned and dunnage laid down. Consider the nature of cargo, and stow it in the various holds so that the vessel will be kept in good trim. The quantity of coal in the bunkers will have to be taken in consideration. If the vessel is to call at a number of ports, the cargo should be stowed so that at the first port of call the cargo for that place will be handy for discharging.

Deadweight should be stowed in the lower holds, and used for trimming the ship; bale goods, etc., on top; tallow and butter should be kept in a cool place away from fire room bulkhead; liquors should be kept in a locker in the tween deck for that purpose.

A cargo of iron ore takes up little space in a vessel, as the ship is down to her draught before the holds are full. This cargo of dead weight should be placed in the body of the vessel, raised up in the main hold, and trimmed out towards the wings, also fore and aft to keep vessel in trim. By stowing cargo high up the vessel will behave better in a seaway.

To carry a cargo of grain in bulk, have all holds cleaned out, and bilges clear. The holds must be divided into compartments by means of fore and aft shifting boards 3″ thick and athwartship bulkheads, the various compartments being grain-tight and strongly constructed from the bottom of the hold right up to the deck. The tween deck must be fitted with feeders to feed the lower hold.

When the grain is coming on board it ought to be well trimmed into all the corners and tramped down, otherwise if the vessel encounters bad weather, she will probably take a heavy list by the cargo settling over to the lee side. All grain cargoes must be properly trimmed, stowed and secured.

If the vessel is not fitted up with properly constructed feeders, she must have not less than one fourth of the grain carried in each hold or compartment made up in bags, and before shipping the bags, matting and platforms must be laid upon the grain in bulk.

Weights should be distributed when loading, about 2/3 in lower holds and 1/3 in tween deck approximately.

Deck cargo should be well secured, and particular attention given to cargo stowed on after deck to keep it clear from steering chains or rods.

A practical rule for ascertaining strength of rope is given below:

Square the circumference and divide by 3 for breaking strain in tons, by 6 for working strain.

To find the weight rope will lift, when rove as a tackle:

Multiply the weight the rope is capable of lifting, by the number of parts at the moving block, and less ¼ for resistance.

To find the number of parts of small rope required to equal a larger rope:

Divide the square of the circumference of the larger rope by the square of the circumference of the smaller, result will be number of parts the smaller rope requires.

SIMPLE RULES IN COMPASS ADJUSTMENT.

Strip compass of all magnets. Suppose the ship to be at sea and intended to use the sun, proceed as follows:

Set your watch to A. T. S., take from the azimuth tables the sun's true bearing for every four minutes of the time during which you will be occupied in adjusting. Correct it into the correct magnetic bearing, and write it down plainly in a small pass book.

SHIP'S HEAD NORTH: Set the lubber's point of the pelorus at North, and the sight vanes clamped to the sun's magnetic bearing. Then starboard or port the helm until the sun's bearing is reflected and bisected by the thread of the pelorus vane. The vessel's head will now be North correct magnetic. If the compass agrees with the pelorus the compass is correct. If the compass shows easterly deviation, place either before or abaft a steel magnet with its red end to starboard above or below in the most convenient place, but on the fore and aft centreline of the compass. Reverse magnets for opposite deviation.

SHIP'S HEAD EAST: Noting the A. T. S. and magnetic bearing of the sun, screw lubber's line of the pelorus East, and keep vanes set to the sun's correct magnetic bearing. Port the helm until the sun is bisected in the sight vanes of the pelorus, steady her carefully on this fresh course. If the compass agrees with the pelorus it should show East, should it fail to do so, the difference is the deviation. If westerly deviation is shown, place a steel magnet fore and aftways on either side of the compass with its red end aft, and centre on the athwartship line of the compass. Move it slowly towards the compass until half of the westerly deviation is corrected. Next place the Flinder's bar forward of the binnacle at such a distance as will cause the ship's head to appear due East, whence it may be securely bolted down to the deck. The semi-circular deviation of the compass is now corrected.

QUADRANTAL DEVIATION: Put ship's head by the pelorus N E (Corr Mgc), noting apparent time as before. In nearly every case the deviation is Easterly. Cast iron cylinders or globes are placed on each side of the compass bowl and moved near to or further from it until the ship's head points N E by the compass also, this adjustment properly made does not require touching everafter, unless some alterations are made in the ironwork near the compass or if the ship were to load a cargo of iron. RULE: The ends of the correctors must not be nearer to the centre of the card than 1¼ times the length of the longest needle. The compass is now fully adjusted, swing the ship for final deviation card.

Semi-Circular deviation is so termed because it has contrary names, thus if it is Easterly on North, it is Westerly on South.

Quadrantal deviation is so termed because it is greatest on the four inter-cardinal points. It has the same name in opposite quadrants, thus, if it is easterly on N E, it will be easterly on S W also, but westerly on S E and N. W. Thus the two kinds of deviation are vastly different.

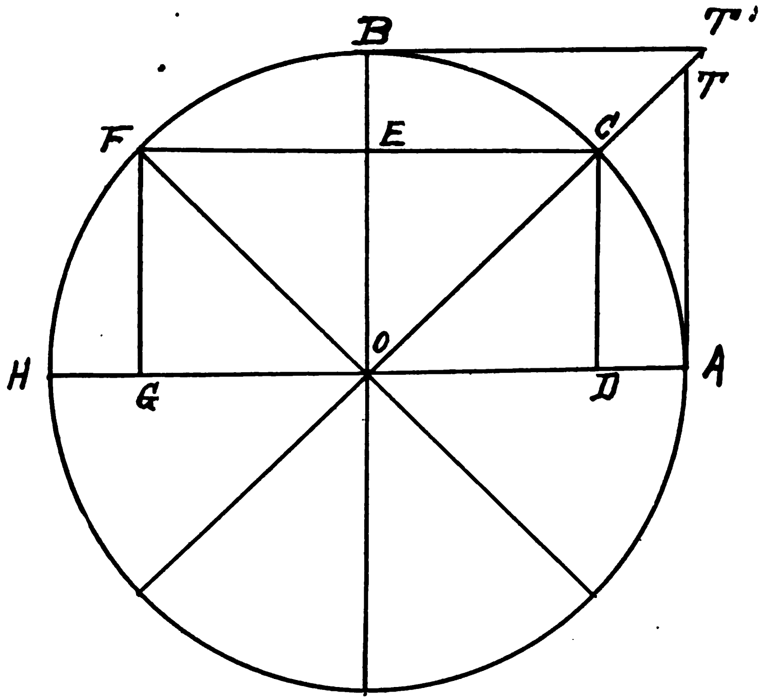
Steel fore and aft magnets produce their greatest effect on East and West, diminishing to nothing on North and South when they become parallel to the compass needle.

Steel athwartship magnets produce their greatest effect on North and South, diminishing to nothing on East and West, when they become parallel to the compass needle.

Quadrantal correctors produce their greatest effect on N E; S E; S W; and N W; tapering to nothing on N; S; E or West.

A flinder's bar placed on the centreline of the compass before or abaft acts in the same way as the fore and aft steel magnets.

EXPLANATION BELOW WILL EXPLAIN DIAGRAM.



No. 1 The Complement of an Arc is 90° minus the Arc. Thus B C is the Complement of the Arc A C.

No. 2. The Supplement of an Arc is 180° minus the Arc. Thus F H is the supplement of the Arc A B F.

No. 3. The Sine of an Arc is the perpendicular let fall from one extremity of the arc on the diameter which passes through the other extremity. Thus C D is the sine of the arc A C.

No. 4. The Cosine of an arc is the sine of its complement, or it is the distance between the foot of the sine and centre of the circle. Thus C E or O D is the cosine of the arc A C.

No. 5. The Tangent of an arc is a line which is perpendicular to the radius at one extremity of the arc and limited by a line passing through the centre of the circle and the other extremity. Thus A T is the tangent of the arc A C.

No. 6. The Cotangent of an arc is equal to the tangent of the complement of arc. Thus B T′ is the cotangent of the arc A C.

No. 7. The Secant of an arc is a line drawn from the centre of the circle through one extremity of the arc, and limited by a tangent at the other extremity. Thus O T is the secant of the arc A C.

No. 8. The Cosecant of an arc is the secant of the complement of the arc. Thus O T′ is the cosecant of the arc A C.

SHIP'S BUSINESS.

INVOICE: Is a bill of goods for stores or supplies or a claim against a vessel for unpaid bills, also a claim to hold cargo for freight unpaid.

BILL OF LADING: A description of cargo, and an agreement to deliver same at a certain place for a certain condition. It is made out in 3 Copies, 1 for Consignor, 1 for Consignee, and 1 for Master, all signed by Master.

MANIFEST: A manifest is a description of cargo, also of passengers if any, and their baggage, also a description of the vessel and its voyage. It should be signed by Master, and should be handed to boarding officer upon arrival at port.

BOTTOMRY BOND: A bottomry bond is where a Master pledges his vessel as security for money loaned to complete voyage.

CHARTER PARTY: A charter party is where the Master, Owner or Agent makes an agreement for the vessel to perform certain services for a certain consideration.

A PROTEST: A protest should be sworn to by Master and members of crew before a Notary, or Consul if abroad. It is a description of some accident happening during the voyage, and protests against blame being placed on ship or crew for accident caused by the elements.

AVERAGE: When it is found necessary to jettison cargo, and some shippers cargo is sacrificed to save the rest of the cargo and ship, a general average is made out so that each should pay their proportionate part.

CHAPTER II.

ARITHMETIC OF NAVIGATION

The arithmetic used in navigation consists of the plain rules of arithmetic (addition, subtraction, multiplication and division). The addition, subtraction, multiplication and division of decimal fractions, and the addition, subtraction and division of degrees, minutes and seconds and hours, minutes and seconds.

The plain rules of arithmetic it is taken for granted the student knows.

ADDITION OF DECIMALS.

In addition of decimals place the numbers that are to be added so that the decimal points will be over each other, and add as a whole number. Place the decimal point in answer under the decimal points in the line.

For example: Add 2894.965; 238.6; and 28.65.

```
       2894.965
        238.6
         28.65
       --------
(Ans)  3162.215
```

SUBTRACTION OF DECIMALS.

In the subtraction of decimals place the decimal point in the numbers so that they will be under each other, and the decimal point in the remainder will be under the decimal point.

For Example: Subtract 2846.65 from 3897.286.

```
        3897.286
      — 2846.65
        --------
(Ans)   1050.636
```

MULTIPLICATION OF DECIMALS.

In the multiplication of decimals multiply as in whole numbers, and count the number of decimal places there are in both numbers, which will be the number of figures counting from the right, where the decimal point goes in the product.

For Example: Multiply 24.48 by 2.6.

```
          24.48
        ×  2.6
        -------
         14688
         4896
        -------
(Ans)    63.648
```

DIVISION OF DECIMALS.

In the division of decimals divide as whole number. If the divisor has more decimals than the dividend, add that many decimal zeros to the dividend before making the division. To place the decimal point, subtract the number of decimals in the divisor from the number of decimal places in the dividend, and point off as many decimal places in the quotient as there are in the remainder.

Example: Divide 322 by .26.

```
.26) 322.000 (1238.4 nearly (Ans)
     26
     ---
      62
      52
     ---
     100
      78
     ---
      220
      208
      ---
       120
       104
       ---
        16
```

ADDITION OF DEGREES, MINUTES AND SECONDS OR HOURS, MINUTES AND SECONDS.

The degrees, minutes and seconds must be directly under their like numbers.

For Example: Add together 26° 47′ 36″ and 51° 27′ 42″.

$$\begin{array}{r} 26^\circ\ 47'\ 36'' \\ 51^\circ\ 27'\ 42'' \\ \hline 78^\circ\ 15'\ 18'' \end{array}$$

Adding the seconds gives 78 — 60 = 18 seconds left, with 1′ to carry. Adding the minutes gives 75′ — 60 = 15′ left, with 1° to carry. Adding degrees gives 78°.

SUBTRACTION.

The numbers must be directly under their like numbers.
For Example: Subtract 40° 52′ 48″ from 76° 29′ 36″.

$$\begin{array}{rr} & 76^\circ\ 29'\ 36'' \\ - & 40^\circ\ 52'\ 48'' \\ \hline \text{(Ans)} & 35^\circ\ 36'\ 48'' \end{array}$$

In subtracting degrees, minutes and seconds or hours, minutes and seconds, if the number of seconds in the minuend is less than the number in subtrahend. You take 1 minute or 60 from the minutes and apply it to the minuend. In this example 36″ is less than 48″, so borrow 1 minute and make it 96″, we then subtract 48″ from this, which leaves 48″. The minutes will then be 28′. It is now necessary to borrow 1 degree, and add 60 to the minutes for the next subtraction which will make 88 — 52 which leaves 36′. The degrees will be 75° left, from which subtract 40° leaves 35°.

DIVISION.

This will be necessary to divide degrees, minutes and seconds by 2. Hours, minutes and seconds by 4.

Example: Divide 38° 57′ 12″ by 2.

$$\begin{array}{rl} 2(& 38^\circ\ 57'\ 12'' \\ \hline & 19^\circ\ 28'\ 36''\ \ \text{(Ans)} \end{array}$$

Divide 4 hours 26′ 10″ by 4.

```
         4 hours is equal to  240′
                             + 26′
                             -----
                           4( 266′
                             -----
                              66 with 2′ left over.
         2 min. is equal to  120″
                            + 10″
                            -----
                          4( 130″
                            -----
                             32′ with 2″ left over.
   2 seconds is equal to 4( 120
                            ----
                             30″
```

Total 66° 32′ 30″.

EXPLANATION OF AMERICAN NAUTICAL ALMANAC FOR THE YEAR 1918.

PAGES 2-3 is the Right Ascension of Mean Sun at Greenwich Mean Noon, and the table below is the correction to be added for Mean Time Greenwich.

For Example: M. T. G. Feby. 18th, 6 hrs. 28′. Required Sun's Right Ascension.

Sun's Right Ascension Feby. 18th	21 hrs. 50′ 33″
Corr for M. T. G. 6 hrs. 28′	+ 1′ 04″
Correct S. R. A.	21 hrs. 51′ 37″

PAGES 6 to 29 is the Sun's Declination, Equation of Time, and Semi-Diameter for Greenwich Mean Noon.

The declination and equation of time are given for every day of the year, and on the even hour.

The declination is read in degrees and minutes and tenths of minutes, the sign + means North declination, the sign — means South declination.

The Equation of time is read in minutes and seconds and tenths of seconds, the sign + means to add to Mean Time, the sign — means to subtract from Mean Time.

To find the Sun's declination and equation of time use the Greenwich date and time always, using the nearest hour of time.

For Example: Feby. 18th M. T. G. 8 hrs. 15′. Required Declination and Equation of time.

Declination for 8 hours 18th 11° 41′ 48″ S. Equation of time — 14′ 06″.

When the hours are uneven, it will be necessary to interpolate between the hours.

For Example: Feby. 18th M. T. G. 9 hrs. 15′. Required Declination and Equation of time.

Decl, for 8 hours	11° 41′ 48″
Decl. for 10 hours	11° 40′ 00″
	2(23° 21′ 48″
Decl. for 9 hours	11° 40′ 54″ S

Equation of time 8 hours	14′ 06″.5
Equation of time 10 hours	14′ 06″.1
	2(28′ 12″.6
Equation of time 9 hours	— 14′ 06″.3

The semi-diameter is given for every 10 days, and is in minutes and hundredths of minutes.

Read semi-diameter to nearest date, and multiply first number in hundredths of minutes by 6 will be close enough.

For Example: Required semi-diameter for Feby. 18th = 16′ 12″.

The hourly difference for declination and equation of time will be found for each date at bottom of date marked H. D. This is the change in 1 hour. It is not necessary to follow this formula with the American Almanac, as the declination and equation of time are given for every 2 hours, but an understanding should be had of it in case of using another almanac.

Take out the declination and equation of time for 0 hours which will be Greenwich noon, and the hourly difference at bottom of page. Multiply hourly difference by hours and tenths of Greenwich time.

For Example: Jan. 20, 1918. M. T. G. 5 hrs. 42′. Find true declination and equation of time.

Sun's Decl. Jan. 20th 0 hrs.	20° 14′ 06″ S	Decl.
Corr. for Decl.	— 2′ 51″	decreasing
True Declination	20° 11′ 15″ S	

Hrly. Diff. .5 = 30″
5.7 Hours M. T. G.

171″ = 2′ 51″ Corr, for declination.

Eq. of Time Jany. 20th	—11′ 01″.8	Equat.
Corr. for Equation	3″.99	increasing
Corr. Eq. of Time	—11′ 05″.79 or 11′ 06″	

Hrly. Diff. .7″
5.7 Hours of M. T. G.

3.99″ Corr. for Equation.

The following rule for applying correction must be followed:

If declination or equation of time is increasing, the correction is to be added.

If declination or equation of time is decreasing, the correction is to be subtracted.

PAGES 30 to 75 is the Moon's Right Ascension, Declination, Semi-Diameter and Horizontal Parallax given for each day, and on the even hours of that day.

The declination and right ascension are accompanied by the difference or change in every 2 hours; by means of these differences interpolation may be made to any Greenwich Mean Time by Table IV, (Almanac) Pages 112-114, using the difference in 2 hours at top of page, and the interval in minutes from nearest even hour on the left hand side of page.

For Example: Feby. 18th M. T. G. 8 hrs. 15′. Required Moon's Declination?

Moon's Decl. Feby. 18 for 8 hrs. is	23° 36′.3 N	Change 44′ Decl. increasing.
Correction from Table IV	+ .5	
True Declination	23° 36′.8 N or 23° 36′ 48″ N	

For same Horizontal Parallax is 57.2. Semi-Diameter 15.6.

PAGES 76 to 77 is the time of Moon's Transit for Meridian of Greenwich.

To find time of transit in any other meridian, Enter Table IV (Almanac). Take the change of transit in small figures between the dates at top of page, and the longitude in time at right hand side and read the correction.

For Example: Required time of Moon's transit on Feby. 18th in Lon. 90° West.

Lon. 90° = Lon. in time 6 hrs.

Moon's Trans. Feby. 18th at Greenwich	6 hrs. 34′
Correction from Table IV	+ 13′
Time of Transit in Lon. 90°	6 hrs. 45′ P. M.

Correction is always to be added in West longitude, subtracted in East longitude.

PAGES 78 to 98 is the Right Ascension, Declination, and time of transit given for Greenwich noon, of the Planets "Venus," "Mars," "Jupiter," and "Saturn."

The interpolations for finding at any other meridian are made by using Table IV (Almanac) with M. T. G. at right hand side, and the difference at top of page.

For example: Required Right Ascension and Declination of Planet "Venus."

M. T. G. Feby. 18th 8 hrs. 15′.

Right Ascension Feby. 18th	21 hrs. 02′ 41″	Change 103 R. A. decreasing
Corr. Table IV	— 34″	
Correct Right Ascension	21 hrs. 02′ 07″	

Declination Feby. 18th =	8° 04.4 S	Change 99. Decl.
Corr. from Table IV	3.4	increasing.
True Decl.	8° 07.8 or 8° 07′ 48″ S	

PAGES 94-95 is the Right Ascension and Declination for fixed stars given for each month.

As the declination and right ascension of a fixed star has a very small annual change, it will be close enough for practical purposes to take it for the month.

Example: Feby. 18, 1918. Required Declination and Right Ascension of Star "Spica."

Declination 10° 44′ 12″ S. Right Ascension 13 hrs. 20′ 54″.

The balance of the tables explain themselves.

EXPLANATION OF TABLES IN BOWDITCH NAVIGATOR OR EPITOME.

TABLE 2.

Is to find the difference of latitude and departure in miles for any course in degrees.

The degrees of the course are found at top of page from 0° to 45°.

The degrees of the course are found at bottom of page from 45° to 90°.

When the course is less than 45° read the table as follows:

Distance in 1st column. Difference in latitude 2d column. Departure 3d column.

When the course is more than 45° read table as follows:

Distance in 1st column. Difference lat. 3d column. Departure 2d column.

For Example:

Course N 38° E. Distance 48 miles. Diff. lat. will be 37.8 N. Departure 29.6 E.

Course N 52° E. Distance 48 miles. Diff. lat. will be 29.6 N. Departure 37.8 E.

To find the difference of longitude ship has made, look for middle latitude as the course, and the departure in miles in the latitude column, in the distance column opposite will be difference of longitude in miles.

For Example:

Middle lat. 38°. Departure 105.6. At 38° look for 105.6 in latitude column, which will equal a distance of 134 miles, which is the difference of longitude in miles, by dividing this by 60, we obtain Diff. Long. 2° 14′. Middle Lat. 52°. Departure 105.6. By same rule we find distance 171, or difference of longitude 2° 51.

To find course and distance ship has run, compare difference of latitude in miles and departure in miles as close as possible, course will be found from top of page if latitude is greatest, from bottom if departure is greatest, and distance will be found on side in distance column.

For Example:

Diff. Lat. 151.3. Departure 118.2. Comparing these we find course 38° distance 192 miles.

Diff. Lat. 118.2. Departure 151.3. We find course 52° distance 192 miles.

TABLE 3.

Used in Mercators Sailing for finding the Meridional difference of latitude in logarithms.

The degrees of latitude are read from top of page, minutes from side.

For Example:

Lat. A 28° 46 N = Mer. Parts Table 3 = 1792.2.

Lat. B 72° 13 N = Mer. Parts Table 3 = 6354.8.

The logarithms of meridional parts are to be added together when degrees and minutes of latitude are added, subtracted when degrees and minutes of latitude are subtracted.

TABLE 7.

Is to convert arc into time, and the reverse.

There is 4 minutes of time to 1 degree of arc, and 4 seconds of time to 1 minute of arc, and this table is based on this principle.

For Example:

To turn Longitude 94° 32 into time. By figures we multiply 94 by 4 and divide by 60, or 94 × 4 = 376 divided by 60 = 6 hrs. 16′, the same rule applies for the minutes, so 32 × 4 = 128 divided by 60 = 2′ 08″. By adding these two together we get 6 hrs. 18′ 08″ longitude in time.

By Table 7 we find that 94° = 6 hrs. 16′ and that 32′ = 2′ 08″. by adding these together we get the same result as above.

The use of this table reduces the amount of figures in computing considerably, but the student should understand the principle it is based on.

To turn longitude in time into degrees and minutes proceed in figures as follows:

Multiply hours by 60 and add the minutes or 6 hrs. × 60 = 360 + 18 = 378, and divide result by four, or 378 divided by 4 = 94° with 2′ left over. Reduce minutes to seconds by same rule and add seconds, or 2′ × 60 = 120 + 8 = 128″ divided by 4 = 32′ or Long. 94° 32.

To use Table 7 proceed as follows:

Take the hour and nearest minute that can be found, which will be 6 hrs. 16′ = 94°. We then have 2′ 08″ left over. Looking for 2′ 08″ we find 32′ or Lon. 94° 32.

When using this table remember that degrees of arc read as hours and minutes of time, minutes of arc as minutes and seconds of time, and seconds of arc as seconds and 1/60″ of time.

TABLE 11.

Is used to find the time of Moon's Meridian Passage over any Meridian.

The difference between Moon's Transit is found from top of page, and longitude of place at side.

The numbers taken from this table are to be added to the time of Greenwich transit in West longitude, subtracted in East longitude.

TABLE 20A.

Is the Mean Refraction. This table is used for the Stars only.

The apparent altitude is read in first column, and the refraction will be found opposite to it.

The refraction is always to be subtracted from apparent altitude.

By apparent altitude is meant, the observed altitude corrected for Index Error if any, and Dip.

For Example:

Appar. Alt. 19° 12′ = Refraction 2′ 46″ to be subtracted.

TABLE 20B.

Is the correction for the Sun's Apparent Altitude for Refraction and Parallax, always to be subtracted.

The apparent altitude is the observed altitude corrected for Index Error if any, Semi-Diameter, and Dip.

For Example:

Appar. Altitude 28° 49 = Refraction and Parallax — 1′ 38″.

TABLE 24.

Is the correction for the Moon's Apparent Altitude for Parallax and Refraction.

With the Horizontal Parallax as found in Nautical Almanac at top of page, and apparent altitude at side, read the correction.

This correction is always to be added to apparent altitude.

Example:

H. P. 54.9 Moon's Appar. Alt. 22° 12 = Par. and Refr. + 48′ 34″.

TABLE 26.

Is the variation of altitude in 1 minute from Meridian Passage.

It is used for finding the latitude by Ex-Meridian observations of a heavenly body.

With declination to nearest degree at top of page, and latitude to nearest degree at side, the variation of altitude in 1 minute will be read.

(Note) Notice whether latitude and declination are same or contrary names.

Example:

Lat. 28° N. Decl. 18° S = Variation 2″.3.

By squaring the number of minutes from noon, and multiplying same by this number, will give correction for sun's altitude always to be added.

For Example:

Time 12 minutes from Noon = 12 × 12 = 144 × 2″.3 = 331″ or 5′ 31″ altitude correction to be added.

TABLE 27.

Is the reduction to be applied to altitudes near the meridian.

This table is based on the principle of the number of minutes from noon squared multiplied by number from Table 26 = altitude correction.

Taking the number found in Table 26 in previous example 2″.3 and time from noon 12 minutes, enter Table 27 with 12′ at top of page and 2.0 on side, we find 4′ 48″ altitude correction. By interpolating between this and number below would give 5′ 31″ altitude correction, if 2.3 was used.

By squaring minutes and multiplying by number from Table 26 eliminates this table.

TABLE 42.

Is the logarithms of numbers from 1 to 9999.

For finding the logarithm of a number proceed as follows:

1, 2 or 3 figures in the number the log will be read alongside of number in 0 column.

4 figures in number, the first 3 numbers will be read on side, and last number from top of page.

Every logarithm has an index number, which is found from following rule:

1 number in the distance the index number will be 0.
2 numbers in the distance the index number will be 1.
3 numbers in the distance the index number will be 2.
4 numbers in the distance the index number will be 3.

For Example:

The Logarithm for No. 8 = 0.90309.
The Logarithm for No. 28 = 1.44716.
The Logarithm for No. 365 = 2.56229.
The Logarithm for No. 4888 = 3.68913.

TABLE 44.

Is the logarithms for Sines, Tangents and Secants.

From 0° to 45° will be found from top of page, and minutes in left hand column reading down.

From 45° to 90° will be found on bottom, minutes on right side reading up.

For Example:

Log. Sine of 18° 48 = 9.50821.
Log. Sine of 71° 12 = 9.97619.

TABLE 45.

Is the table for Log. Haversines and Nat. Haversines.

The Log. Haversine is in light type. The Nat. Haversine in heavy type.

When looking for Log. Haversine of A. T. S. if the sight is A. M., the hours and minutes of time are read from bottom of page, and the seconds from right hand column reading up the page.

When the hours and minutes are taken from the bottom of page, the astronomical date will be the date before the civil date which is given in example.

For Example:

Feby. 9th A. M. at ship. Log. Haversine as found from sum of logs = 9.38624. Log. Haversine 9.38624 = Apparent Time Ship Feby. 8th 20 hrs. 03′ 32″.

If the sight is P. M. the hours and minutes will be found on top in light type, and the astronomical date will be the same as civil date, and the seconds will be found on left hand side reading down the page.

For Example:

Feby. 9th P. M. at ship. Log Haversine 9.38624 = A. T. S. Feby. 9th 3 hrs. 56′ 28″.

For turning longitude in time into degrees, minutes and seconds proceed as follows: Read hours and minutes of longtitude in time at top, seconds in left hand column.

For Example:

Turn longitude in time 3 hrs. 56′ 28″ into degrees, minutes and seconds.

For 3 hrs. 56′ we find 59° 00 for 28″ we find + 7′ or Long 59° 07.

To find the Nat. Haversine look for Log. Haversine and alongside of it will be Nat. Haversine.

For Example:

Log. Haversine 9.38624 = Nat. Haversine .24335.
and
Nat. Haversine .24335 = 59° 07
Nat. Haversine .24339 = 59° 07′ 15″
Nat. Haversine .24342 = 59° 07′ 30″
Nat. Haversine .24345 = 59° 07′ 45″

TABLE 46.

Is the correction to be applied to an observed altitude of sun or star to find true altitude.

This table does away with the necessity for applying the Semi-Diameter, Dip, Refraction and Parallax to sun's altitude, and dip and refraction to star's altitude.

The height of eye will be found at top of page, and obs. altitude at side, and the correction for the sun in 1st column to be added, and to the star in 2d column to be subtracted.

For Example:

Sun's Obs Alt. 28° 50. Dip 28 ft. = Corr. + 9′ 15″ or True Alt. 28° 59′ 15″.

Star's Obs. Alt. 28° 50. Dip 28 ft. = Corr. — 6′ 53″ or True Alt. 28° 43′ 07″.

This shortens the work of correcting the altitude considerably, but the student should understand the other method before using this table.

CHAPTER III.

DAY'S WORK, OR SHIP'S POSITION BY DEAD RECKONING.

This problem is to find the ship's position when no observations are obtainable. It is accurate as long as the proper distance on each course is allowed, and leeway, deviation, and variation is correct.

The leeway is the amount the ship is drifting to leeward from the compass course, and is by the judgment of the navigator set to so many degrees or points of the compass.

The deviation is the difference between the compass course and the magnetic course, and is explained under Deviation of the Compass.

The variation is the difference between the magnetic course and true course, and is explained under Variation of the Compass.

To convert a compass course into a true course allow Easterly deviation and variation to the right of the compass course; Westerly to the left always imagining yourself standing in the centre of the compass and looking toward the course you are steering.

To convert a true course into a compass course, allow East to left; West to right.

The departure course is the bearing of the point of departure by a compass. This course must be reversed (imagining the ship to have sailed from the point to the place you are at time of taking the bearing), and corrected for the deviation and variation for the ship's head, making the bearing true, and entered in the traverse table as a regular course.

The courses are then corrected for Leeway, deviation and variation, and entered in traverse table.

The current course is the amount and direction the current has set the ship for the day, and is corrected for Variation only, and entered in traverse table as a regular course.

The traverse table is drawn and the true courses and distance of each entered.

The difference of Lat. and departure is found for each course and distance, from Table 2 (Bowditch) and entered in traverse table.

The difference of latitude is the amount of latitude North or South in miles the ship has run on the course.

The departure is the amount of easting or westing in miles the ship has made on the course.

The latitude and departure columns are then added up separately, and the less subtracted from the greater.

The amount of each left will be the Difference of Lat. North or South, and Departure East or West.

The latitude left is now put down and the difference of latitude converted into degrees, minutes and seconds, allowing 60 miles to 1 degree of latitude from the equator to the poles.

Applying this difference of latitude to latitude left will give the latitude arrived at.

A degree of longitude is worth 60 miles on the equator or Lat. 0° but on account of the curvature of the earth there is no longitude at the poles or Lat. 90°. It is then necessary to find the value of a degree of longitude halfway between the latitude left and latitude arrived at, we then proceed as follows:

To find Middle Latitude: Add together, Lat. left and Lat. In, and divide sum by 2. Answer will be Middle Latitude.

The longitude left is now put down and the difference of longitude is found as follows:

Enter Table 2 (Bowditch) with middle latitude to nearest degree as a regular course, look in the latitude column for the difference of Departure, and in the Distance column will be the difference of longitude in miles.

Convert this difference of longitude in miles into degrees, minutes and seconds by dividing by 60, and apply to longitude left. Answer will be longitude arrived at.

The latitude and longitude arrived at will be the position of the vessel by dead reckoning.

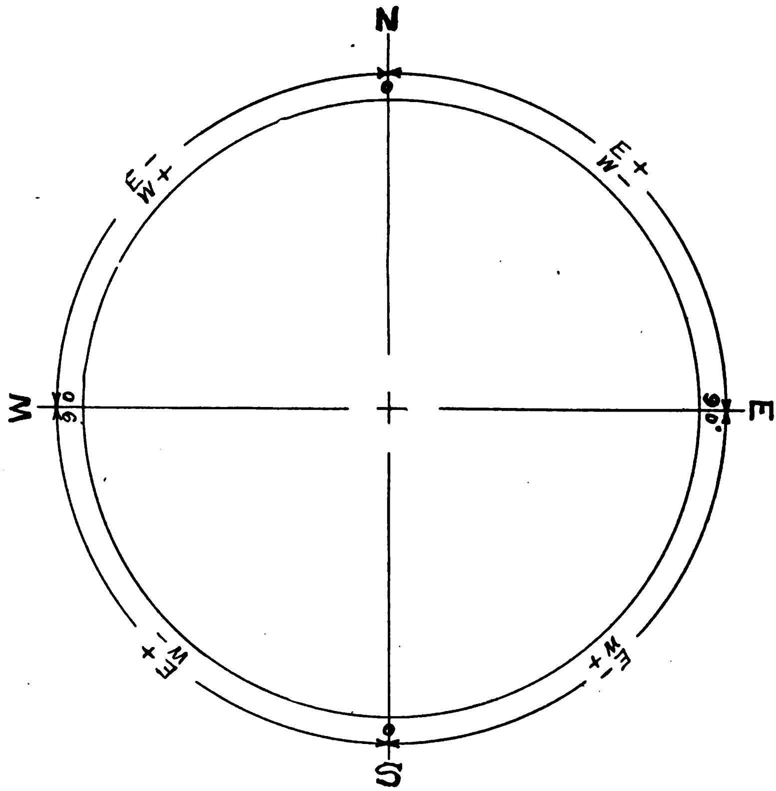
To find the true course and distance made in a straight line between the places, enter Table 2 (Bowditch) and compare the difference of Latitude in miles with the Departure in miles as close as possible.

Where these two compare will be the course and distance.

The course will be found from top of page if Difference of latitude is greatest number.

From bottom of page if Departure is greatest number.

In the distance column opposite to where these agree will be the distance ship has run.



DIAGRAM

For Coverting Compass Courses Into True Courses.

Allow Easterly deviation and variation to the right.
Allow Westerly deviation and variation to the left.

To Convert A True Course Into A Compass Course.

Allow Easterly deviation and variation to the left
Allow Westerly deviation and variation to the right.

To Convert A True Course Into A Magnetic Course.

Allow for variation only, to the left for Easterly, to the right for Westerly.

To Convert A Compass Course Into A Magnetic Course.

Allow for deviation only, To the right for Easterly, to the left for Westerly.

PROBLEM No. 1.

A ship takes her departure from Lat. 28° 14′ 00″ N. Long. 79° 30 W and sails the following courses:

Courses	Distance	Deviation	Variation
N 20° W	26	4° E	8° W
S 16° E	31	4° W	8° W
S 80° W	35	6° E	8° W
S 70° E	40	12° W	8° W
N 40° E	45	6° E	8° W
North	50	3° E	8° W

Required Lat. and Lon. arrived at. True course and distance made?

1st Course.

N 20° W
Dev. 4° E to right

N 16° W
Var. 8° W to left

N 24° W (true)

2nd Course.

S 16° E
Dev. 4° W to left

S 20° E
Var. 8° W to left

S 28° E (true)

3d Course.

S 80° W
Dev. 6° E to right

S 86° W
Var. 8° W to left

S 78° W (true)

4th Course.

S 70° E
Dev. 12° W to left

S 82° E
Var. 8° W to left

East (true)

5th Course.

N 40° E
Dev. 6° E to right

N 46° E
Var. 8° W to left

N 38° E (true)

6th Course.

North
Dev. 3° E to right

N 3° E
Var. 8° W to left

N 5° W (true)

Corrected Courses.	Distance.	Difference Latitude. North.	South.	Departure: East.	West.
N 24° W	26	23.8			10.6
S 28° E	31		27.4	14.6	
S 78° W	35		7.3		34.2
East	40			40.0	
N 38° E	45	35.5		27.7	
N 5° W	50	49.8			4.4
		109.1	34.7	82.3	49.2
		34.7		49.2	
	Diff. Lat.	74.4 N	Dep.	33.1 E	

Latitude left	28° 14′ 00″ N
Diff. Lat.	1° 14′ 24″ N
Latitude In	29° 28′ 24″ N
2(	57° 42′ 24″
Middle Lat.	28° 51′ 12″ or 29°

Longitude left	79° 30 W
Diff. Long.	38 E
Longitude In	78° 52 W

True course N 24° E. Distance 81 miles.

PROBLEM No. 2.

Ship takes her departure from a point in Lat. 37° 03 N Long. 9° 00 W bearing by compass N 48° E distance 15 miles. Ship's head S 67° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
S 67° W	45	N W	6°	11° W	22° W
N 39° W	49	S W	3°	17° W	22° W
N 22° W	38	West	9°	11° W	22° W
N 56° W	31	S W	14°	20° W	22° W
S 39° W	36	S E	11°	6° W	22° W
S 84° W	41	South	6°	14° W	22° W

Current set S 65° W (Corr. Mgc.) 8 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

PROBLEM No. 2.

METHOD OF CONVERTING COMPASS COURSES INTO TRUE COURSES, BEFORE ENTERING IN TRAVERSE TABLE.

No. 1.

Bearing course N 48° E to be reversed and read
S 48° W
Dev. 11° W to left

S 37° W
Var. 22° W to left

S 15° W (true)

No. 2.

S 67° W
6° Leeway to left

S 61° W
Dev. 11° W to left

S 50° W
Var. 22° W to left

S 28° W (true)

No. 3.

N 39° W
3° Leeway to right

N 36° W
17° W Dev. to left

N 53° W
22° W Var. to left

N 75° W (true)

No. 4.

N 22° W
9° Leeway to right

N 13° W
11° W Dev. to left

N 24° W
22° W Var. to left

N 46° W (true)

No. 5.

N 56° W
14° Leeway to right

N 42° W
20° W Dev. to left

N 62° W
22° W Var. to left

N 84° W (true)

No. 6.

S 39° W
11° Leeway to right

S 50° W
6° W Dev. to left

S 44° W
22° W Dev. to left

S 22° W (true)

No. 7.

S 84° W
6° Leeway to right
———
W 90°
14° W Dev. to left
———
S 76° W
22° W Var. to left
———
S 54° W (true)

No. 8 Current.

S 65° W set of current magnetic.
22° W Variation
———
S 43° W set of current true.

The true courses are now entered in traverse table with their distance in the distance column, and the difference of latitude and departure found for each in Table 2.

ANSWER TO PROBLEM NO. 2.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
S 15° W	15		14.5		3.9
S 28° W	45		39.7		21.1
N 75° W	49	12.7			47.3
N 46° W	38	26.4			27.3
N 84° W	31	3.2			30.8
S 22° W	36		33.4		13.5
S 54° W	41		24.1		33.2
S 43° W	8		5.9		5.5
		42.3	117.6	Dep.	182.6W
			42.3		
		Diff. Lat.	75.3 S		

Latitude left	37° 03′ 00″ N
Diff. Lat.	1° 15′ 18″ S
Lat. In	35° 47′ 42″ N
Lat. left	37° 03′
	2(72° 50′ 42″
Middle Lat.	36° 25′ 21″ or 36°

Longitude left	9° 00 W
Diff. Long.	3° 46 W
Long. In	12° 46 W

True Course S 68° W. Distance 197 miles.

PROBLEM No. 3.

A ship takes her departure from a point in Lat. 28° 16′ 15″ N Long. 93° 26 W and sails the following courses:

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
North	50	West	4°	6° E	18° W
N 20° W	52	West	5°	8° W	18° W
West	53	North	6°	7° E	18° W
S 49° W	54	North	7°	8° W	18° W
S 79° W	55	North	7°	9° E	18° W
South	56	West	20°	7° E	18° W
S 10° E	57	West	8°	6° W	18° W

Current set East (Corr. Mgc.) 8 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 3.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 8° W	50	49.5			7.0
N 41° W	52	39.2			34.1
S 73° W	53		15.5		50.7
S 16° W	54		51.9		14.9
S 63° W	55		25.0		49.0
S 31° E	56		48.0	28.8	
S 42° E	57		42.4	38.1	
N 72° E	8	2.5		7.6	
		91.2	182.8	74.5	155.7
			91.2		74.5
		Diff. Lat.	91.6 S	Dep.	81.2W

Latitude left	28° 16′ 15″ N
Diff. Lat.	1° 31′ 36″ S
Lat. In	26° 44′ 39″ N
Lat. left	28° 16′ 15″
2(	55° 00′ 54″
Middle Lat.	27° 30′ 27″ or 27°

Longitude left	93° 26 W
Diff. Lon.	1° 31 W
Long. In	94° 57 W

True course S 42° W. Distance 123 miles.

PROBLEM No. 4.

A ship takes her departure from a point in Lat. 21° 12 N Long 8° 15 E bearing by compass N 20° W. Distance 12 miles. Ship's head S 45° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
S 45° W	40	South	3°	8° E	7° W
S 80° W	41	South	8°	4° E	7° W
N 75° W	42	S W	4°	5° E	7° W
N 45° W	43	West	3°	3° W	7° W
North	44	East	2°	4° W	7° W
N 10° E	45	East	3°	5° E	7° W

Current set East (Corr. Mgc.) 12 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 4.

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
S 19° E	12		11.3	3.9	
S 49° W	40		26.2		30.2
S 85° W	41		3.6		40.8
N 73° W	42	12.3			40.2
N 52° W	43	26.5			33.9
N 13° W	44	42.9			9.9
N 5° E	45	44.8		3.9	
N 83° E	12	1.5		11.9	
		128.0	41.1	19.7	155.0
		41.1			19.7
	Diff. Lat.	86.9 N		Dep.	135.3W

Latitude left	21° 12′ 00″	N
Diff. Lat.	1° 26′ 54″	N
Lat. In	22° 38′ 54″	N
Lat. left	21° 12′	
	2(43° 50′ 54″	
Middle Lat.	21° 55′ 27″	or 22°
Longitude left	8° 15	E
Diff. Long.	2° 26	W
Long. In	5° 49	E

True course N 57° W. Distance 161 miles.

PROBLEM No. 5.

A ship takes her departure from a point in Lat. 18° 14′ 12″ S Long. 156° 12 E bearing by compass N 89° E distance 12 miles. Ship's head North.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
North	60	East	2°	12° W	6° E
N 20° W	61	N E	4°	8° W	6° E
N 50° W	62	North	3°	4° E	6° E
N 80° W	63	North	4°	5° E	6° E
S 80° W	64	N W	5°	6° W	6° E
S 15° W	65	West	4°	14° W	6° E

Current set S 15° E (Corr. Mgc.) 18 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 5.

Corrected.	Distance.	Difference Lat.		Departure.	
Courses.		North.	South.	East.	West.
S 83° W	12		1.5		11.9
N 8° W	60	59.4			8.4
N 26° W	61	54.8			26.7
N 43° W	62	45.3			42.3
N 73° W	63	18.4			60.2
S 75° W	64		16.6		61.8
S 3° W	65		64.9		3.4
S 9° E	18		17.8	2.8	
		177.9	100.8	2.8	214.7
		100.8			2.8
	Diff. Lat.	77.1 N		Dep.	211.9W

Latitude left	18° 14′ 12″ S
Diff. Lat.	1° 17′ 06″ N
Lat. In	16° 57′ 06″ S
Lat. left	18° 14′ 12″
	2(35° 11′ 18″
Middle Lat.	17° 35′ 39″ or 18°
Longitude left	156° 12 E
Diff. Long.	3° 42 W
Long. In	152° 30 E

True course N 70° W. Distance 225 miles.

PROBLEM No. 6.

A ship takes her departure from a point in Lat. 62° 12 S Long. 171° 12 E bearing by compass East distance 12 miles. Ship's head S 15° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
S 15° W	62	West	4°	8° W	18° E
South	64	S W	5°	9° W	18° E
West	66	North	6°	7° E	18° E
N 45° W	68	West	3°	19° W	18° E
S 59° W	70	South	6°	8° W	18° E
N 50° W	72	S W	7°	10° W	18° E

Current set S 15° E (Corr. Mgc.) 18 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 6.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 80° W	12	2.1			11.8
S 21° W	62		57.9		22.2
S 4° W	64		63.8		4.5
N 71° W	66	21.5			62.4
N 43° W	68	49.7			46.4
S 75° W	70		18.1		67.6
N 35° W	72	59.0			41.3
S 3° W	18		18.0		0.9
		132.3	157.8	Dep.	257.1W
			132.3		
		Diff. Lat.	25.5 S		

Latitude left	62° 12′ 00″ S	
Diff. Lat.	25′ 30″ S	
Lat. In	62° 37′ 30″ S	
Lat. left	62° 12′	
	2(124° 49′ 30″	
Middle Lat.	62° 24′ 45″	or 62°

Longitude left	171° 12 E
Diff. Long.	9° 08 W
Long. In	162° 04 E

True Course S 84° W. Distance 258 miles.

PROBLEM No. 7.

A ship takes her departure from a point in Lat. 36° 56 N Long. 75° 51 W bearing by compass N 67° W distance 7 miles. Ship's head S 56° E.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
S 56° E	50	East	3°	4° W	8° E
S 23° E	40	East	2°	2° W	8° E
South	20	East	4°	12° W	8° E
East	60	North	8°	3° E	8° E
N 73° E	30	North	4°	4° W	8° E
N 51° E	40	North	3°	3° E	8° E

Current set S 46° W (Corr. Mgc.) 14 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
S 63° E	7		3.2	6.2	
S 49° E	50		32.8	37.7	
S 15° E	40		38.6	10.4	
South	20		20.0		
S 71° E	60		19.5	56.7	
N 81° E	30	4.7		29.6	
N 65° E	40	16.9		36.3	
S 54° W	14		8.2		11.3
		21.6	122.3	176.9	11.3
			21.6	11.3	
		Diff. Lat.	100.7 S	165.6	Dep. E

Latitude left	36° 56′ 00″	N
Diff. Lat.	1° 40′ 42″	S
Lat. In	35° 15′ 18″	N
	2(72° 11′ 18″	
Middle Lat.	36° 05′ 39″	or 36°

Longitude left	75° 51	W
Diff. Lon.	3° 25	E
Long. In	72° 26	W

True Course S 59° E. Distance 193 miles.

PROBLEM No. 8.

A ship takes her departure from a point in Lat. 0° 21′ N Lon. 178° 21 E bearing by compass S 21° E distance 13 miles. Ship's head N 18° E.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
N 18° E	60	East	4°	7° E	9° W
N 3° W	61	N E	5°	4° E	9° W
N 45° W	62	N E	3°	1° W	9° W
West	63	North	2°	6° E	9° W
S 50° W	64	N W	1°	2° E	9° W
South	65	West	2°	6° E	9° W

Current set S 15° E (Corr. Mgc.) 24 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 8.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 23° W	13	12.0			5.1
N 12° E	60	58.7		12.5	
N 13° W	61	59.4			13.7
N 58° W	62	32.9			52.6
S 85° W	63		5.5		62.8
S 42° W	64		47.6		42.8
S 5° E	65		64.8	5.7	
S 24° E	24		21.9	9.8	
		163.0	139.8	28.0	177.0
		139.8			28.0
		Diff. Lat. 23.2 N			Dep. 149.0W

Latitude left	0° 21′ 00″ N	
Diff. Lat.	23′ 12″ N	
Lat. In	0° 44′ 12″ N	
	2(1° 05′ 12″	
Middle Latitude	° 32′ 36″	or 1°

Longitude left	178° 21 E
Diff. Long.	2° 29 W
Long. In	175° 52 E

True Course N 81° W. Distance 151 miles.

PROBLEM No. 9.

A ship takes her departure from a point in Lat. 3° 10′ 12″ S Long. 0° 15 W bearing by compass N 10° W distance 14 miles. Ship's head S 15° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
S 15° W	40	S E	4°	3° W	40° E
S 15° E	41	East	5°	8° W	40° E
East	42	South	6°	1° E	40° E
N 70° E	43	South	4°	4° W	40° E
N 45° E	44	North	2°	1° E	40° E
N 15° E	45	East	1°	2° E	40° E

Current set N 16° W (Corr. Mgc.) 18 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 9.

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
S 27° W	14		12.5		6.4
S 56° W	40		22.4		33.2
S 22° W	41		38.0		15.4
S 55° E	42		24.1	34.4	
S 78° E	43		8.9	42.1	
N 88° E	44	1.5		44.0	
N 56° E	45	25.2		37.3	
N 24° E	18	16.4		7.3	
		43.1	105.9	165.1	55.0
			43.1	55.0	

Diff. Lat. 62.8 S 110.1 Dep. E

Latitude left	3° 10′ 12″ S
Diff. Lat.	1° 02′ 48″ S
Lat. In	4° 13′ 00″ S
2(	7° 23′ 12″
Middle Latitude	3° 41′ 36″ or4°

Longitude left	0° 15 W
Diff. Long.	1° 51 E
Long. In	1° 36 E

True Course S 60° E. Distance 127 miles.

PROBLEM No. 10.

A ship takes her departure from a point in Lat. 67° 15′ 08″ N Long. 112° 12 W bearing by compass S 80° W distance 20 miles. Ship's head North.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
North	50	East	3°	4° E	21° W
N 40° W	51	N E	2°	9° E	21° W
N 15° W	52	N E	3°	3° E	21° W
West	53	North	2°	26° E	21° W
N 70° W	54	North	1°	2° E	21° W
S 89° W	55	South	3°	4° E	21° W

Current set S 22° E (Corr. Mgc.) 14 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 10.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 63° E	20	9.1		17.8	
N 20° W	50	47.0			17.1
N 54° W	51	30.0			41.3
N 36° W	52	42.1			30.6
N 87° W	53	2.8			52.9
West	54				54.0
S 75° W	55		14.2		53.1
S 43° E	14		10.2	9.5	
		131.0	24.4	27.3	249.0
		24.4			27.3
		Diff. Lat. 106.6 N			Dep. 221.7W

Latitude left	67° 15′ 08″	N
Diff. Lat.	1° 46′ 36″	N
Lat. In	69° 01′ 44″	N
	2(136° 16′ 52″	
Middle Lat.	68° 08′ 26′	or 68°

Longitude left	112° 12	W
Diff. Long.	9° 52	W
Long. In	122° 04	W

True Course N 64° W. Distance 246 miles.

PROBLEM No. 11.

A ship takes her departure from a point in Lat. 0° 00 Long. 0° 00 bearing by compass South distance 18 miles. Ship's head East.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
East	70	S E	2°	12° E	18° W
S 45° E	71	South	8°	5° E	18° W
S 15° E	72	East	3°	25° E	18° W
South	73	East	4°	8° E	18° W
S 10° W	74	East	2°	4° E	18° W
S 45° W	75	S E	1°	6° E	18° W

Current set N 8° W (Corr. Mgc.) 19 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 11.

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
N 6° W	18	17.9			1.9
N 82° E	70	9.7		69.3	
S 66° E	71		28.9	64.9	
S 5° E	72		71.7	6.3	
S 6° E	73		72.6	7.6	
S 2° E	74		74.0	2.6	
S 34° W	75		62.2		41.9
N 26° W	19	17.1			8.3
		44.7	309.4	150.7	52.1
			44.7	52.1	
		Diff. Lat.	264.7 S	98.6	Dep. E

Latitude left	0° 00′ 00″
Diff. Lat.	4° 24′ 42″ S
Lat. In 2(	4° 24′ 42″ S
Middle Lat.	2° 12″ 21″ or 2°

Longitude left	0° 00′ 00″
Diff. Long.	1° 38′ 45″ E
Long. In	1° 38′ 45″ E

True Course S 20° E. Distance 281 miles.

PROBLEM No. 12.

A ship takes her departure from a point in Lat. 51° 37 N Long. 8° 32 W bearing by compass N 45° W distance 12 miles. Ship's head S 17° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
S 17° W	26	West	3°	5° E	24° W
S 53° W	30	N W	3°	9° W	24° W
S 67° W	50	N W	6°	12° W	24° W
N 3° W	38	N W	9°	4° W	24° W
S 51° E	32	S W	0°	11° E	24° W

Current set N 79° W (Corr. Mgc.) 14 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 12.

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
S 64° E	12		5.3	10.8	
S 5° E	26		25.9	2.3	
S 17° W	30		28.7		8.8
S 25° W	50		45.3		21.1
N 22° W	38	35.2			14.2
S 64° E	32		14.0	28.8	
S 77° W	14		3.1		13.6
		35.2	122.3	41.9	57.7
			35.2		41.9
		Diff. Lat.	87.1 S	Dep.	15.8W

Latitude left	51° 37′ 00″	N
Diff. Lat.	1° 27′ 06″	S
Lat. In	50° 09′ 54″	N
	2(101° 46′ 54″	
Middle Lat.	50° 53′ 27″	or 51°

Longitude left	8° 32	W
Diff. Long.	25	W
Long. In	8° 57	W

True Course S 10° W. Distance 89 miles.

PROBLEM No. 13.

A ship takes her departure from a point in Lat. 62° 11 N Long. 5° 08 E bearing by compass S 28° W distance 10 miles. Ship's head N 22° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
N 22° W	39	N E	6°	7° W	20° W
N 68° W	36	North	8°	18° W	20° W
S 28° W	39	S E	3°	9° W	20° W
S 11° E	40	East	0°	3° E	20° W
S 6° E	35	S W	11°	2° E	20° W
N 23° E	31	N W	14°	6° E	20° W

Current set S 56° W (Corr. Mgc.) 36 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 13.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 1° E	10	10.0		0.2	
N 55° W	39	22.4			31.9
S 66° W	36		14.6		32.9
S 2° W	39		39.0		1.4
S 28° E	40		35.3	18.8	
S 35° E	35		28.7	20.1	
N 23° E	31	28.5		12.1	
S 36° W	36		29.1		21.2
		60.9	146.7	51.2	87.4
			60.9		51.2
		Diff. Lat.	85.8 S	Dep.	36.2W

Latitude left	62° 11′ 00″	N
Diff. Lat.	1° 25′ 48″	S
Lat. In	60° 45′ 12″	N
	2(122° 56′ 12″	
Middle Lat.	61° 28′ 06°	or 61°

Longitude left	5° 08 E
Diff. Long.	1° 15 W
Long. In	3° 53 E

True Course S 23° W. Distance 93 miles.

PROBLEM No. 14.

A ship takes her departure from a point in Lat. 47° 34 N Long 52° 40 W bearing by compass N 70° W distance 17 miles. Ship's head N 84° E.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
N 84° E	20	S E	14°	9° E	31° W
N 20° E	33	East	6°	11° E	31° W
S 42° E	35	N E	3°	4° E	31° W
N 70° W	35	S W	5°	6° W	31° W
N 53° E	37	N W	3°	4° E	31° W
S 64° E	28	N E	5°	3° W	31° W

Current set N 73° E (Corr. Mgc.) 17 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 14.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 88° E	17	0.6		17.0	
N 48° E	20	13.4		14.9	
N 6° W	33	32.8			3.4
S 66° E	35		14.2	32.0	
S 78° W	35		7.3		34.2
N 29° E	37	32.4		17.9	
N 87° E	28	1.5		28.0	
N 42° E	17	12.6		11.4	
		93.3	21.5	121.2	37.6
		21.5		37.6	

Diff. Lat. 71.8 N   Dep. 83.6 E

Latitude left	47° 34′ 00″ N
Diff. Lat.	1° 11′ 48″ N
Lat. In	48° 45′ 48″ N
	2(96° 19′ 48″
Middle Lat.	48° 09′ 54″ or 48°

Longitude left	52° 40 W
Diff. Long.	2° 05 E
Long. In	50° 35 W

True Course N 49° E. Distance 111 miles.

PROBLEM No. 15.

A ship takes her departure from a point in Lat. 38° 43 S Long. 77° 35 E bearing by compass S 28° E distance 16 miles. Ship's head N 56° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
N 56° W	35	North	11°	16° W	25° W
S 34° E	40	S W	3°	11° E	25° W
S 6° W	41	S E	0°	2° W	25° W
N 87° W	37	North	6°	26° W	25° W
N 28° E	34	N W	20°	8° E	25° W
S 11° E	37	East	8°	3° E	25° W

Current set S 56° E (Corr. Mgc.) 39 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 15.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 69° W	16	5.7			14.9
S 72° W	35		10.8		33.3
S 51° E	40		25.2	31.1	
S 21° E	41		38.3	14.7	
S 36° W	37		29.9		21.7
N 31° E	34	29.1		17.5	
S 25° E	37		33.5	15.6	
S 81° E	39		6.1	38.5	
		34.8	143.8	117.4	69.9
			34.8	69.9	
		Diff. Lat.	109.0 S	47.5	Dep. E

Latitude left	38° 43′ 00″ S
Diff. Lat.	1° 49′ 00″ S
Lat. In	40° 32′ 00″ S
	2(79° 15′ 00″
Middle Lat.	39° 37′ 30″ or 40°

Longitude left	77° 35 E
Diff. Long.	1° 02 E
Long. In	78° 37 E

True Course S 23° E. Distance 119 miles.

PROBLEM No. 16.

A ship takes her departure from a point in Lat. 61° 19 N Long. 179° 19 E bearing by compass N 56° W distance 18 miles. Ship's head N 23° E.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
N 23° E	34	N W	11°	6° E	20° E
N 56° E	40	North	3°	16° E	20° E
N 86° E	30	South	14°	21° E	20° E
S 23° W	26	S E	28°	7° W	20° E
N 73° W	30	North	20°	19° W	20° E
S 23° E	36	S W	8°	7° E	20° E

Current set S 56° E (Corr. Mgc.) 38 miles for day.

Required Lat. and Long. arrived at. True course and distance?

ANSWER TO PROBLEM No. 16.

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
S 30° E	18		15.6	9.0	
N 60° E	34	17.0		29.4	
S 85° E	40		3.5	39.8	
S 67° E	30		11.7	27.6	
S 64° W	26		11-4		23.4
S 88° W	30		1.0		30.0
S 4° E	36		35.9	2.5	
S 36° E	38		30.7	22.3	
		17.0	109.8	130.6	53.4
			17.0	53.4	
		Diff. Lat.	92.8 S	77.2 Dep. E	

Latitude left	61° 19′ 00″ N
Diff. Lat.	1° 32′ 48″ S
Lat. In	59° 46′ 12″ N
	2(121° 05′ 12″
Middle Lat.	60° 32′ 36″ or 61°

Longitude left	179° 19 E
Diff. Long.	2° 39 E
Long. In	178° 02 W

True Course S 40° E. Distance 121 miles.

PROBLEM No. 17.

A ship takes her departure from a point in Lat. 40° 19 S Long. 9° 44 W bearing by compass East distance 20 miles. Ship's head N 39° W.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
N 39° W	22	S W	3°	3° E	20° W
N 23° W	23	West	3°	8° E	20° W
N 23° E	18	N W	6°	20° E	20° W
S 48° E	19	N W	0°	6° W	20° W
S 34° E	10	S W	0°	9° W	20° W
N 3° W	42	West	3°	14° E	20° W

Current set N 73° W (Corr. Mgc.) 36 miles for day.

ANSWER TO PROBLEM No. 17.

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
S 73° W	20		5.8		19.1
N 53° W	22	13.2			17.6
N 32° W	23	19.5			12.2
N 29° E	18	15.7		8.7	
S 74° E	19		5.2	18.3	
S 63° E	10		4.5	8.9	
N 6° W	42	41.8			4.4
S 87° W	36		1.9		36.0
		90.2	17.4	35.9	89.3
		17.4			35.9
	Diff. Lat.	72.8 N		Dep.	53.4W

Latitude left	40° 19′ 00″ S
Diff. Lat.	1° 12′ 48″ N
Lat. In	39° 06′ 12″ S
	2(79° 25′ 12″
Middle Lat.	39° 42′ 36″ or 40°
Longitude left	9° 44 W
Diff. Lon.	1° 10 W
Long. In	10° 54 W

True Course N 36° W. Distance 90 Miles.

PROBLEM No. 18.

Ship takes her departure from a point in Lat. 49° 42 S Long. 178° 42 E and sails the following courses:

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
N 42° E	35	S E	5°	21° E	14° E
N 73° E	36	North	3°	15° E	14° E
S 48° W	37	S E	3°	15° W	14° E
S 17° E	26	East	9°	13° W	14° E
N 8° E	33	East	8°	18° E	14° E
N 14° W	38	N E	3°	12° E	14° E

Current set N 56° E (Corr. Mgc.) 28 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 18.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
N 72° E	35	10.8		33.3	
S 75° E	36		9.3	34.8	
S 50° W	37		23.8		28.3
S 7° E	26		25.8	3.2	
N 32° E	33	28.0		17.5	
N 9° E	38	37.5		5.9	
N 70° E	28	9.6		26.3	
		85.9	58.9	121.0	28.3
		58.9		28.3	
		Diff. Lat. 27.0 N		Dep. 92.7 E	

Latitude left	49° 42′ 00″ S
Diff. Lat.	27′ 00″ N
Lat. In	49° 15′ 00″ S
	2(98° 57′ 00″
Middle Lat.	49° 28′ 30″ or 49°

Longitude left	178° 42 E
Diff. Long.	2° 20 E
Long. In	178° 58 W

True Course N 73° E. Distance 96 miles.

PROBLEM No. 19.

A ship takes her departure from a point in Lat. 28° 14 S Long. 102° 16 E bearing by compass S 68° E distance 14 miles. Ship's head North.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
North	60	West	4°	7° W	9° E
N 28° W	61	S W	5°	3° E	9° E
N 28° E	62	East	3°	12° E	9° E
S 87° E	63	North	2°	4° W	9° E
S 15° E	64	S W	4°	14° W	9° E
East	65	North	3°	8° W	9° E

Current set S 23° W (Corr. Mgc.) 19 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 19.

Corrected. Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
N 66° W	14	5.7			12.8
N 6° E	60	59.7		6.3	
N 11° W	61	59.9			11.6
N 46° E	62	43.1		44.6	
S 80° E	63		10.9	62.0	
S 24° E	64		58.5	26.0	
S 86° E	65		4.5	64.8	
S 32° W	19		16.1		10.1
		168.4	90.0	203.7	34.5
		90.0		34.5	

Diff. Lat. 78.4 N Dep. 169.2 E

Latitude left	28° 14′ 00″ S
Diff. Lat.	1° 18′ 24″ N
Lat. In	26° 55′ 36″ S
	2(55° 09′ 36″
Middle Lat..	27° 34′ 48″ or 28°

Longitude left	102° 16 E
Diff. Long.	3° 12 E
Long. In	105° 28 E

True Course N 65° E. Distance 187 miles.

PROBLEM No. 20.

A ship takes her departure from a point in Lat. 24° 16 N Long. 37° 18 W bearing by compass East distance 9 miles. Ship's head South.

Courses.	Distance.	Wind.	Leeway.	Deviation.	Variation.
South	70	East	4°	5° W	10° E
S 45° W	71	N W	5°	3° W	10° E
West	72	North	4°	9° E	10° E
N 80° W	73	South	4°	4° W	10° E
S 15° W	74	West	2°	3° W	10° E
N 45° W	75	N E	3°	8° W	10° E

Current set East (Corr. Mgc.) 17 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

ANSWER TO PROBLEM No. 20.

Corrected.	Distance.	Difference Lat.		Departure.	
Courses.		North.	South.	East.	West.
N 85° W	9	0.8			9.0
S 9° W	70		69.1		11.0
S 47° W	71		48.4		51.9
N 75° W	72	18.6			69.5
N 70° W	73	25.0			68.6
S 20° W	74		69.5		25.3
N 46° W	75	52.1			54.0
S 80° E	17		3.0	16.7	
		96.5	190.0	16.7	289.3
			96.5		16.7
		Diff.	Lat. 93.5 S	Dep.	272.6W

Latitude left	24° 16′ 00″ N
Diff. Lat.	1° 33′ 30″ S
Lat. In	22° 42′ 30″ N
	2(46° 58′ 30″
Middle Lat.	23° 29′ 15″ or 23°

Longitude left	37° 18 W
Diff. Long.	4° 56 W
Long. In	42° 14 W

True Course S 71° W. Distance 288 miles.

PROBLEM No. 21.

I steered S 18° W by Compass, Error 18° E, Var. 7° E, 16 miles, N 18° W Magnetic, Error 18° E, Var. 7° E, 16 miles.

How would I have to steer to get back to where I started from, and if Cape Flyaway (Lat. 43° 17′ N Long. 73° 18′ E) bore North (True) 21 miles, what would be my position?

Corrected

Courses.	Dist.	N.	S.	E.	W.
S 36 W	16		12.9		9.4
N 11 W	16	15.7			3.1
		15.7	12.9	Dep.	12.5W
		12.9			
	D. Lat.	2.8 N			

Course to steer to get back to point of Departure S 78° E 13 miles.

Cape Flyaway Lat.	43° 17′ N	Long. 73° 18′ E
Different Lat.	21′ S	
Ship's Position Lat.	42° 56′ N	Long. 73° 18′ E

PROBLEM No. 22.

At sea in Lat. 26° 12′ N Long. 88° 13′ W. Received wireless that South Pass Lt. vessel had been adrift 47 hours. Current setting E. S. E. (Mgc.) 3 miles per hour. Now at anchor. Please find Lt. vessel and tow her back to her position Lat. 28° 59′ N Long. 89° 07′ W, Var. 5° E.

Find true course and distance to Lt. vessel and course and distance back to her position.

Corrected

Course.	Dist.	N.	S.	E.	W.
S 62 E	141		66.2	124.5	

Position of Lt. Vessel Lat.	28° 59′ N
Diff. Lat.	1° 06′ S
Present Position Lt. Vessel	27° 53′ N
Ship's Position Lat.	26° 12′ N
Diff. Lat.	1° 41′ N

Long. of L. V	89° 07′ W
D Long.	2° 21′ E
Present Long. of L. V.	86° 46′ W
Ship's Pos. Long.	88° 13′ W
D. Long.	1° 27′ E

D. Lat. 101 N Dep. 77.5 E

Course and distance to Lt. Vessel N 38 E 127 miles.

Course and distance back to Lt. Vessel's Station N 62 W 141 miles.

PROBLEM No. 23.

A ship sailed from Point Neverbudge, Lat. 41° 00′ S Long. 86° 15′ E, the following courses:

South true 14 miles.

South by Compass, Error 6 E, Var. 6 W, 14 miles.

East by Compass, Dev. 4 E, Var. 6 W, 24 miles.

West by Compass, Dev. 6 E, Var. 6 W, 24 miles.

North by Compass, Dev. 16 E, Var. 6 W, 28 miles.

Find course and distance made good and Lat. and Long. arrived at.

Corrected		Diff. Lat.		Diff. Dep.	
Courses.	Dist.	N.	S.	E.	W.
South	14		14.0		
S 6 W	14		13.9		1.5
N 88 E	24	0.8		24.0	
West	24				24.0
N 10 E	28	27.6		4.9	
		28.4	27.9	28.9	25.5
		27.9		25.5	

Diff. Lat. .5 N Dep. 3.4 E

Lat. left	41° 00′ 00″ S	Long. left	86° 15′ 00″ E
Diff. Lat.	30″ N	Diff. Long.	4′ 30″ E
Lat. Ar. at	40° 59′ 30″ S	Long. Ar. at	86° 19′ 30″ E
Mid. Lat.	(41°)		

Course N 80 E. Distance 3 miles.

PROBLEM No. 24.

From Nantucket Shoals Lt. Ship (Lat. 40° 37′ N Long. 69° 36′ W) bearing North (True) 10 miles. Error 7° W. I steered N 75° W by Compass Var. 12° 30′ W Dev. 7° 30′ E for 95 miles. How would Block Island S E Lt. (Lat. 41° 09′ N Long. 71° 33′ W) bear True?

Corrected Courses.	Dist.	N.	S.	E.	W.
South	10		10		
N 80 W	95	16.5			93.6
		16.5	10	Dep.	93.6W
		10			

Diff. Lat. 6.5 N

Nantucket Sh. Lt. Ship Lat.	40° 37′ 00″ N
Difference Latitude	6′ 30″ N
Position of Ship Lat.	40° 43′ 30″ N
Block Island Lt. Lat.	41° 09′ 00″ N
Diff. Lat	25′ 30″ N

Mid. Lat. 41° Diff. Lat. 25.5 N.

Nantucket Shoal L. S. Long.	69° 36′ W
Diff. Long.	2° 04′ W
Position of Ship Long.	71° 40′ W
Block Island. Lt. Long.	71° 33′ W
Diff. Long.	7′ E

Dep. 5.3 E.

True bearing N 12° E. 26 miles.

PROBLEM No. 25.

Steer East (Mgc.)
North (True).
West (True).
South (Mgc.)

Steamed 12 knots for one hour on each course.

Variation for the 4 hours 7° W.

Find position of ship if you left Lat. 43° 17′ N Long. 73° 14′ E.

Corrected Courses.	Dist.	N.	S.	E.	W.
N 83 E	12	1.5		11.9	
North	12	12.0			
West	12				12.0
S 7 E	12		11.9	1.5	
		13.5	11.9	13.4	12.0
		11.9		12.0	
	Diff. Lat.	1.6 N	Dep.	1.4 E	

Lat. left	43° 17′ 00″ N	Long. left	73° 14′ E
Diff. Lat.	1′ 36″ N	Diff. Long.	2′ E
Lat. Ar. at	44° 18′ 36″ N	Long. Ar. at	73° 16′ E

Course N 39° E. Distance 2 miles.

PROBLEM No. 26.

A ship from Point Neverbudge (Lat. 42° 25′ N Long. 86° 15′ E), steered the following courses:

South (True) 14 miles.

East by Compass, Error 6° E, Var. 6 W, 14 miles.

N 15 E by Compass, Dev. 9° W, Var. 6° W, 15 miles.

S 4 W (Mgc.), Dev. 7° E, Var. 6° W, 19 miles.

S 17 E by Compass, Dev. 9° E, Var. 6° W, 25 miles.

Find course and distance made good and Latitude and Longitude arrived at.

Corrected Courses.	Dist.	N.	S.	E.	W.
South	14		14.0		
S 84 E	14		1.5	13.9	
North	15	15			
S 2 E	19		19.0	0.7	
S 14 E	25		24.3	6.0	
		15	58.8	20.6 E Dep.	
			15.0		
		Diff. Lat.	43.8 S		

Lat. left	42° 25′ 00″	Long. left	86° 15′ E
Diff. Lat.	43′ 48″ S	Diff. Long.	28′ E
Lat. Ar. at	41° 41′ 12″ N	Long. Ar. at	86° 43′ E

Mid. Lat. 42°

Course S 25° E. Distance 48 miles.

U. S. NAVY METHOD.

A ship takes her departure at Noon heading 210° (p. s. c.) with Point Pinos Lighthouse, Cal., abeam distance 7 miles. Pat. Log read 81.

At 5 P. M. changed course to 280°. Patent Log 50.
At 8 P. M. changed course to 350°. Patent Log 1.
At 2 A. M. changed course to 270°. Patent Log 90.
At 6 A. M. changed course to 180°. Patent Log 47.
At 9 A. M. changed course to 110°. Patent Log 86.
At Noon Patent Log read 28.

Current set for day 60° (Mgc.) at rate of 1¼′.

Variation on all courses 22° E. Use deviation table from Page 41 (Bowditch).

Required Noon position, and course and distance made.

Point Pinos on California coast.

1st course is bearing. If ship was heading 210° when bearing was taken, and lighthouse was abeam, the lighthouse must have been 90° from 210° or to the eastward of the ship, being on the California coast. So we find

	210°	
	— 90°	
	120°	bearing of L. H.
	+180°	
	300°	bearing reversed.
Dev.	27°	E. as per ship's head.
	327°	
Var.	22°	E
True	349°	7 miles.

No. 2.

Course	210°	Log 5 P. M.	50
Dev.	27 +	Log Noon	—81
	237°	Dist.	69
Var.	22°+		
True	259° = 69 miles.		

No. 3.

	280°	Log	50
Dev.	4°+	Log	1
	284°		51
Var.	22°+		
True	306°	Dist. 51.	

No. 4.

	350°	
Dev.	16 —	
	334°	
Var.	22°+	
True	356°	Dist. 89.

No. 5.

	270°	
Dev.	10°+	
	280	
Var.	22 +	
True	302°	Dist 57′

No. 6.

	180°	
Dev.	18 +	
	198	
Var.	22 +	
True	220°	Dist. 39′.

No. 7.

	110°	
Dev.	9 —	
	101	
Var.	22 +	
True	123°	Dist. 42′.

No. 8.

24 hrs. at 1¼ miles per hour.
Current 60°
Var. 22°+

True 82° Dist. 30′.

Corrected. Courses.	Distance.	Difference Lat. North.	South.	Departure. East.	West.
349°	7	6.9			1.3
259°	69		13.2		67.7
306°	51	30.0			41.3
356°	89	88.8			6.2
302°	57	30.2			48.3
220°	39		29.9		25.1
123°	42		22.9	35.2	
82°	30	4.2		29.7	
		160.1	66.0	64.9	189.9
		66.			64.9

Diff. Lat. 94.1 N Dep. 125.0W

Latitude left	36° 37′ 55″ N
Diff. Lat.	1° 34′ 06″ N
Latitude In	38° 12′ 01″ N
	2(74° 49′ 56″
Middle Lat.	37° 24′ 58″
Longitude left	121° 56′ 02″ W
Diff. Long.	2° 37′ 00″ W
Longitude In	124° 33′ 02″ W

True course 307°. Distance 157 miles.

U. S. NAVY METHOD.

A ship takes her departure at 4 P. M. heading 93° Dev. 4° W (p. s. c.) with Nantucket South Shoal Lightship, Mass., abeam, distance 9 miles. Patent log read 77.

At 7 P. M. changed course to 170° P. L. 16 Dev. 9° W.
At 11 P. M. changed course to 189° P. L. 67 Dev. 10° W.
At 1 A. M. changed course to 115° P. L. 94 Dev. 6° W.
At 4 A. M. changed course to 70° P. L. 32 Dev. 1° W.
At 8 A. M. changed course to 90° P. L. 84 Dev. 4° W.

Variation on all courses 11° W.

At noon log read 36.
Current set 286° (Mgc.) at rate of 1 2-3 miles per hour.
Required noon position. True course and distance.

Corrected Courses.	Distance.	Difference Lat. North.	Difference Lat. South.	Departure. East.	Departure. West.
168°	9		8.8	1.9	
78°	39	8.1		38.1	
150°	51		44.2	25.5	
168°	27		26.4	5.6	
98°	38		5.3	37.6	
58°	52	27.6		44.1	
75°	52	13.5		50.2	
275°	33	2.9			32.9
		52.1	84.7	203.0	32.9
			52.1	32.9	
		Diff. Lat.	32.6 S	170.1 Dep. East	

Latitude left	40° 37′ 05″	N
Diff. Lat.	32′ 36″	S
Latitude In	40° 04′ 29″	N
	2(80° 41′ 34″	
Middle Lat.	40° 20′ 47″	
Longitude left	69° 36′ 33″	W
Diff. Long.	3° 42	E
Longitude In	65° 54′ 33″	W

True course 101°. Distance 173 miles.

CHAPTER IV.

MERCATORS SAILING.

This problem is to find the course and distance in a straight line between two places.

The latitude and longitude A is the point of starting, and the latitude and longitude B is the place bound for.

The latitude A and latitude B and longitude A and longitude B are put down under each other, and the difference between the places is found in degrees, minutes and seconds by the following rule:

Both of the same name, subtract. Different name, add the two.

If the degrees of longitude exceed 180°, subtract total from 360°.

The degrees and minutes are turned into miles by multiplying the degrees by 60, and adding to the result the miles.

A Mercator chart is constructed on the principle that the earth is a flat plane, and the degrees of longitude are equal, and the degrees of latitude are increased from the equator to the poles to allow for the decrease in the degrees of longitude.

From Table 3 (Bowditch) take out the Meridional Parts for the degrees and minutes of each latitude, which are the logarithms for the increase of the degrees of latitude.

Add or subtract these logs, same as was done with the degrees and minutes of latitude in the problem.

In Table 42 (Bowditch) will be found Logarithms of Numbers. All logs. of numbers have an index number which is found by table below:

2 figures in the distance the index number is 1.
3 figures in the distance the index number is 2.
4 figures in the distance the index number is 3.

When the number is of 2 or 3 figures the log is read in the 0 column alongside of the number given.

When the number has 4 figures the first 3 numbers of the figures are read on the side, and the last number at top of page.

Take out from Table 42 log of difference of longitude in miles, adding 10 to the index number, and log of meridional parts, index number by rule above.

Subtract log of meridional parts from log of difference of longitude.

The Log. Tangent in Table 44 (Bowditch) that agrees with answer will be the course in degrees and minutes.

If the index number for Tangent is 8 or 9 the course will be from top of page.

If the index number for Tangent is 10 or 11 the course will be from bottom of page.

Take out the Log. Secant from Table 44 for the degrees and minutes of the course, rejecting the 10 from the index number.

Take out the log of difference of latitude (Table 42) applying its index number by rule above.

Add together Log. Secant of course, and log of difference of latitude.

The log that agrees with this sum in the body of the logs Table 42, will be the distance in the left hand column for the first 3 numbers, and the number of the column log was found in on top will be the last number.

If the index number is 1 the distance will be in 2 figures.
If the index number is 2 the distance will be in 3 figures.
If the index number is 3 the distance will be in 4 figures.

PROBLEM No. 1.

Lat. A 43° 08 N	Mer. Parts 2858.0	Long. A 5° 56 E
Lat. B 39° 29 N	Mer. Parts 2567.5	Long. B 0° 24 W
3° 39	290.5	6° 20
60		60
180		360
+ 39		+ 20
D. Lat. 219		Diff. Lon. 380

Log of Diff. Long. 380 = 12.57978
Log of Mer. Parts 290.5 = 2.46315

Tangent 10.11663 = Course S 52° 36 W

Secant of Course 52° 36 = 0.21654
Log of Diff. Lat. 219 = 2.34044

Log 2.55698 = Dist. 360.6 miles.

PROBLEM No. 2.

Lat. A 15° 55 S	Mer. Parts	961.1	Long. A 5° 44 W
Lat. B 55° 59 S	Mer. Parts	4052.7	Long. B 67° 16 W
Diff. Lat. 2404′	Mer. Parts	3091.6	Diff. Long. 3692′

Log of Diff. Long. 3692 = 13.56726
Log of Mer. Parts 3092 = 3.49024

Tangent 10.07702 = Course S 50° 03 W

Secant of Course 50° 03 = 0.19238
Log of Diff. Lat. 2404 = 3.38093

Log 3.57331 = Dist. 3744 miles.

PROBLEM No. 3.

Lat. A 15° 12 S	Mer. Parts	916.8	Long. A 2° 12 E
Lat. B 28° 49 S	Mer. Parts	1795.6	Long. B 17° 11 E
Diff. Lat. 817′ S	Mer. Parts	878.8	Diff. Long. 899′

Log of Diff. Long. 899 = 12.95376
Log of Mer. Parts 878.8 = 2.94389

Tangent 10.00987 = Course S 45° 39 E

Secant of Course 45° 39 = 0.15550
Log of Diff. Lat. 817′ = 2.91222

Log 3.06772 = Dist. 1169 miles.

PROBLEM No. 4.

Lat. A 17° 15 S	Mer. Parts	1044.1	Long. A 92° 21 W
Lat. B 31° 42 S	Mer. Parts	1994.9	Long. B 110° 10 W
Diff. Lat. 867′	Mer. Parts	950.8	Diff. Long. 1069′

Log of Diff. Long. 1069 = 13.02898
Log of Mer. Parts 950.8 = 2.97809

Tangent 10.05089 = Course S 48° 21 W

Secant of Course 48° 21 = 0.17745
Log of Diff. Lat. 867 = 2.93802

Log 3.11547 = Dist. 1305 miles.

PROBLEM No. 5.

Lat. A 18° 12 S	Mer. Parts 1103.5	Long. A 18° 10 E
Lat. B 46° 11 S	Mer. Parts 3114.5	Long. B 32° 21 W
Diff. Lat. 1679′	Mer. Parts 2011	Diff. Long. 3031′

Log of Diff. Long. 3031 = 13.48159
Log of Mer. Parts 2011 = 3.30341

Tangent 10.17818 = Course S 56° 26 W

Secant of Course 56° 26 = 0.25735
Log of Diff. Lat. 1679 = 3.22505

Log 3.48240 = Dist. 3037 miles.

PROBLEM No. 6.

Lat. A 30° 29 N	Mer. Parts 1910.1	Long. A. 179° 47 E
Lat. B 15° 12 N	Mer. Parts 916.8	Long. B 126° 44 E
Diff. Lat. 917.	Mer. Parts 993.3	Diff. Long. 3183

Log. of Diff. Long. 3183 = 13.50284
Log. of Mer. Parts 993.3 = 2.99708

Tangent 10.50576 = Course S 72° 40 W

Secant of Course 72° 40 = 0.52589
Log of Diff. Lat. 917 = 2.96237

Log 3.48826 = Dist. 3078 miles.

PROBLEM No. 7.

Lat. A 8° 05 S	Mer. Parts 483.3	Lon. A 18° 02 W
Lat. B 62° 04 S	Mer. Parts 4762.8	Long. B 103° 03 W
Diff. Lat. 3239′	Mer. Parts 4279.5	Diff. Long. 5101′

Log of Diff. Long. 5101 = 13.70766
Log of Mer. Parts 4279 = 3.63134

Tangent 10.07632 = Course S 50° 01 W

Secant of Course 50° 01 = 0.19208
Log of Diff. Lat. 3239 = 3.51041

Log 3.70249 = Dist. 5041 miles.

PROBLEM No. 8.

Lat. A 0° 00	Mer. Parts0000.0	Long. A 0° 02 W
Lat. B 51° 12 N	Mer. Parts3569.7	Long. B 16° 14 E
Diff. Lat. 3072′	Mer. Parts3569.7	Diff. Long. 976′

Log of Diff. Long. 976 = 12.98945
Log of Mer. Parts 3569 = 3.55255

Tangent 9.43690 = Course N 15° 18 E

Secant of Course 15° 18 = 0.01567
Log of Diff. Lat. 3072 = 3.48742

Log 3.50309 = Dist. 3185 miles.

PROBLEM No. 9.

Lat. A 71° 02 S	Mer. Parts 6129.7	Long. A 16° 12 E
Lat. B 22° 05 S	Mer. Parts 1350.3	Long. B 102° 15 E
Diff. Lat. 2937′	Mer. Parts 4779	Diff. Long. 5163′

Log of Diff. Lon. 5163 = 13.71290
Log of Mer. Parts 4779 = 3.67934

Tangent 10.03356 = Course N 47° 13 E

Secant of Course 47° 13 = 0.16798
Log of Diff. Lat. 2937 = 3.46790

Log 3.63588 = Dist. 4324 miles.

PROBLEM No. 10.

Lat. A 14° 12 S	Mer. Parts 855.1	Long. A 178° 02 E
Lat. B 79° 02 S	Mer. Parts 8033.2	Long. B 115° 16 W
Diff. Lat. 3890′	Mer. Parts 7178.1	Diff. Long. 4002′

Log. of Diff. Long. 4002 = 13.60228
Log of Mer. Parts 7178 = 3.85600

Tangent 9.74628 = Course S 29° 08 E

Secant of Course 29° 08 = 0.05877
Log of Diff. Lat. 3890 = 3.58995

Log 3.64872 = Dist. 4454 miles.

PROBLEM No. 11.

Lat. A	3°	12	N	Mer. Parts	190.8	Long. A	118°	00	W
Lat. B	79°	15	N	Mer. Parts	8102.2	Long. B	142°	12	W

Diff. Lat. 4563′ Mer. Parts 7911 Diff. Long. 1452′

Log. of Diff. Long. 1452 = 13.16197
Log of Mer. Parts 7911 = 3.89823

Tangent 9.26374 = Course N 10° 24 W

Secant of Course 10° 24 = 0.00719
Log of Diff. Lat. 4563 = 3.65925

Log 3.66644 = Dist. 4639 miles.

PROBLEM No. 12.

Lat. A	19°	36	N	Mer. Parts	1191.8	Long. A	18°	12	E
Lat. B	21°	42	S	Mer. Parts	1325.6	Long. B	2°	06	W

Diff. Lat. 2478′ Mer. Parts 2517 Diff. Long. 1218′

Log of Diff. Long. 1218 = 13.08565
Log of Mer. Parts 2517 = 3.40088

Tangent 9.68477 = Course S 25° 49 W

Secant of Course 25° 49 = 0.04566
Log of Diff. Lat. 2478 = 3.39410

Log 3.43976 = Dist. 2753 miles.

PROBLEM No. 13.

Lat. A	36°	08	N	Mer. Parts	2314.1	Long. A	159°	00	E
Lat. B	17°	17	S	Mer. Parts	1046.1	Long. B	159°	00	W

Diff. Lat. 3205′ Mer. Parts 3360 Diff. Long. 2520′

Log of Diff. Long. 2520 = 13.40140
Log of Mer. Parts 3360 = 3.52634

Tangent 9.87506 = Course S 36° 52 E

Secant of Course 36° 52 = 0.09689
Log of Diff. Lat. 3205 = 3.50583

Log 3.60272 = Dist. 4006 miles.

PROBLEM No. 14.

Lat. A 9° 18 S	Mer. Parts 556.7	Long. A 74° 13 E
Lat. B 42° 17 S	Mer. Parts 2788.9	Long. B 47° 17 E
Diff. Lat. 1979′	Mer. Parts 2232.2	Diff. Long. 1616′

Log of Diff. Long. 1616 = 13.20844
Log of Mer. Parts 2232 = 3.34869

Tangent 9.85975 = Course S 35° 54 W

Secant of Course 35° 54 = 0.09149
Log. of Diff. Lat. 1979 = 3.29645

Log 3.38794 = Dist. 2443 miles.

PROBLEM No. 15.

Lat. A 14° 06 N	Mer. Parts 849.0	Long. A 81° 59 W
Lat. B 32° 55 N	Mer. Parts 2080.8	Long. B 59° 17 W
Diff. Lat. 1129′	Mer. Parts 1232	Diff. Long. 1362′

Log of Diff. Long. 1362 = 13.13418
Log of Mer. Parts 1232 = 3.09061

Tangent 10.04357 = Course N 47° 52 E

Secant of Course 47° 52 = 0.17337
Log of Diff. Lat. 1129 = 3.05269

Log 3.22606 = Dist. 1683 miles.

PROBLEM No. 16.

Lat. A 0° 06 N	Mer. Parts 6.0	Long. A 0° 00
Lat. B 60° 10 N	Mer. Parts 4527.1	Long. B 41° 02 W
Diff. Lat. 3604′	Mer. Parts 4521	Diff. Long. 2462′

Log of Diff. Long. 2462 = 13.39129
Log of Mer. Parts 4521 = 3.65523

Tangent 9.73606 = Course N 28° 34 W

Secant of Course 28° 34 = 0.05638
Log of Diff. Lat. 3604 = 3.55678

Log 3.61316 = Dist. 4103 miles.

PROBLEM No. 17.

Lat. A 34° 22 S	Mer. Parts 2184.9	Long. A 18° 24 E
Lat. B 15° 55 S	Mer. Parts 961.1	Long. B 5° 45 W
Diff. Lat. 1107′	Mer. Parts 1224	Diff. Long. 1449′

Log of Diff. Long.	1449 =	13.16107	
Log of Mer. Parts	1224 =	3.08778	
	Tangent	10.07329	= Course N 49° 49 W
Secant of Course	49° 49 =	0.19028	
Log of Diff. Lat.	1107 =	3.04415	
	Log	3.23443	= Dist. 1716 miles.

PROBLEM No. 18.

Lat. A 8° 04 S	Mer. Parts 482.3	Long. A 34° 53 W
Lat. B 14° 45 N	Mer. Parts 889.0	Long. B 17° 32 W
Diff. Lat. 1369′	Mer. Parts 1371	Diff. Long. 1041′

Log of Diff. Long.	1041 =	13.01745	
Log of Mer. Parts	1371 =	3.13704	
	Tangent	9.88041	= Course N 37° 12 E
Secant of Course	37° 12 =	0.09880	
Log of Diff. Lat.	1369 =	3.13640	
	Log	3.23520	= Dist. 1719 miles.

CHAPTER V.

MIDDLE LATITUDE SAILING.

This method is to find the course and distance between two places, when the distance is small.

Proceed as in Mercators sailing to find the difference of latitude and longitude in miles.

Find the Middle Latitude between the places as in Day's Work.

Take the Middle Latitude to the nearest degree as a course, and in Table 2 (Bowditch) look in the Distance column for the difference of longitude in miles, and in the Latitude column corresponding to this distance will be the Departure in miles.

Compare the difference of latitude in miles and Departure in miles in Table 2, and the course and distance will be found as in Day's Work.

PROBLEM No. 1.

Lat. A 28° 17 N	28° 17		Long. A 14° 16 W
Lat. B 30° 02 N	30° 02		Long. B 23° 10 W
1° 45′	58° 19		8° 54
Diff. Lat. 105′	29° 09	Mid. Lat.	
			Diff. Long. 534′
			Departure 467′.

Course N 77° W. Distance 479 miles.

PROBLEM No. 2.

Lat. A 38° 16 S	38° 16		Long. A 102° 12 E
Lat. B 40° 12 S	40° 12		Long. B 108° 11 E
1° 56	78° 28		5° 59
Diff. Lat. 116′	39° 14	Mid. Lat.	
			Diff. Lon. 359′
			Departure 279.0.

Course S 67° E. Distance 303 miles.

PROBLEM No. 3.

Lat. A 76° 08 S	76° 08	Long. A 179° 53 E
Lat. B 74° 16 S	74° 16	Long. B 178° 10 W
1° 52	150° 24	1° 57
Diff. Lat. 112′	75 12 Mid. Lat.	
		Diff. Long. 117′
		Departure 30.3.

Course N 15° E. Distance 116 miles.

PROBLEM No. 4.

Lat. A 42° 08 N	42° 08	Long. A 18° 23 E
Lat. B 47° 05 N	47° 05	Long. B 21° 06 E
4° 57	89° 13	2° 43
Diff. Lat. 297′	44° 36 Mid. Lat.	
		Diff. Long. 163′
		Departure 115.3.

Course N 21° E. Distance 318 miles.

PROBLEM No. 5.

Lat. A 51° 53 N	51° 53	Long. A 37° 18 W
Lat. B 56° 18 N	56° 18	Long. B 40° 17 W
4° 25	108° 11	2° 59
Diff. Lat. 265′	54° 05 Mid. Lat.	
		Diff. Long. 179′
		Departure 105.2.

Course N 22° W. Distance 286 miles.

PROBLEM No. 6.

Lat. A 43° 10 S	43° 10	Long. A 108° 00 W
Lat. B 40° 08 S	40° 08	Long. B 109° 40 W
3° 02	83° 18	1° 40
Diff. Lat. 182′	41° 39 Mid. Lat.	
		Diff. Long. 100′
		Departure 74.3.

Course N 22° W. Distance 196 miles.

PROBLEM No. 7.

Lat. A 12° 13 S	12° 13	Long. A 14° 18 E
Lat. B 9° 16 S	9° 16	Long. B 17° 03 E
2° 57	21° 29	2° 45
Diff. Lat. 177′	10° 44 Mid. Lat.	
		Diff. Long. 165′
		Departure 162.0.

True Course N 42° E. Distance 239 miles.

PROBLEM No. 8.

Lat. A 49° 06 N	49° 06	Long. A 179° 15 E
Lat. B 51° 10 N	51° 10	Long. B 179° 32 W
2° 04	100° 16	1° 13
Diff. Lat. 124′	50° 08 Mid. Lat.	
		Diff. Long. 73′
		Departure 46.9.

Course N 21° E. Distance 133 miles.

PROBLEM No. 9.

Lat. A 38° 07 N	38° 07	Long. A 13° 12 E
Lat. B 36° 51 N	36° 51	Long. B 19° 06 E
1° 16	74° 58	5° 54
Diff. Lat. 76′	37° 29 Mid. Lat.	
		Diff. Long. 354′
		Departure 282.7.

Course S 75° E. Distance 292 miles.

PROBLEM No. 10.

Lat. A 14° 28 S	14° 28	Long. A 0° 06 W
Lat. B 10° 19 S	10° 19	Long. B 7° 18 E
4° 09	24° 47	7° 24
Diff. Lat. 249′	12° 23 Mid. Lat.	
		Diff. Long. 444′
		Departure 434.3.

Course N 60° E. Distance 501 miles.

PROBLEM No. 11.

Lat. A 6° 14 N	6° 14	Long. A 28° 13 E
Lat. B 14° 16 N	14° 16	Long. B 26° 09 E
8° 02	20° 30	2° 04
Diff. Lat. 482′	10° 15 Mid. Lat.	
		Diff. Long. 124′
		Departure 122.1.

Course N 14° W. Distance 497 miles.

PROBLEM No. 12.

Lat. A 60° 10 N	60° 10	Long. A 4° 16 W
Lat. B 58° 11 N	58° 11	Long. B 6° 18 W
1° 59	118° 21	2° 2
Diff. Lat. 119′	59° 10 Mid. Lat.	
		Diff. Long. 122′
		Departure 62.8.

Course S 28° W. Distance 135 miles.

CHAPTER VI.

LATITUDE BY MERIDIAN ALTITUDE OF SUN.

The latitude by sun is found at noon only, when the sun is on the meridian, or the highest point reached by the sun on that day.

The longitude of a place is expressed in degrees, minutes and seconds East or West of Greenwich, England, which is Longitude 0°.

A chronometer always shows Greenwich time, and is explained in the definitions on navigation.

A degree of longitude is worth 4 minutes of time, and 1 minute of longitude is worth 4 seconds of time.

To turn longitude into time enter Table 7 (Bowditch). The degrees of longitude will give the hours and minutes of time, and the minutes of longitude will give the minutes and seconds of time. These two added together, will be the longitude in time.

If in West longitude the ship will be so many hours and minutes of time past Greenwich noon. To obtain Greenwich time proceed as follows: Add the longitude in time to 0 hours and the answer will be the approximate Greenwich time on same date as example.

If in East longitude the ship will be so many hours and minutes of time before Greenwich noon. To obtain Greenwich time proceed as follows: Subtract longitude in time from 24 hours and the answer will be the approximate Greenwich time on date before example.

The declination of a heavenly body is the angular distance North or South of the equator expressed in degrees, minutes and seconds. The sign — in almanac means South declination, the sign + North declination. It is given in the Nautical Almanac for each day, and on the even hours of that day.

With the Approximate Greenwich time and date take out the declination from the almanac. Using the nearest hour of time. If the hour is even it will be read readily, if odd it will be necessary to add the two it is between and divide the sum by 2.

The meridian altitude of a body is the angular distance in degrees, minutes and seconds as read by a sextant, of the body above the sea horizon, when it is on the meridian, or the highest point on that date, and will bear North or South from the observer.

The Index Error is the error of the sextant used for taking the observation, and is applied to Mer. Alt. by the sign given + or —.

The Semi-Diameter is half the diameter of the sun, or the distance from the bottom or top of the sun to the centre. In L L (or lower limb) sights it is added to altitude. In U L (or upper limb) sights it is subtracted. It is always found in Nautical Almanac, using nearest date to example.

The dip is the height above sea level of the observer. It is always subtracted from altitude, and is found from Table 14 (Bowditch).

The refraction is the change of direction of a ray of light in passing through the atmosphere.

The parallax is the apparent displacement of a heavenly body as seen from two different stations.

The parallax and refraction are combined together in Table 20B (Bowditch) and are subtracted from altitude.

After making these corrections to observed meridian altitude, the answer will be true altitude.

The angular distance from the horizon to straight over observer's head is 90°, named the Zenith.

Having found true altitude we subtract it from 90°, and the result will be named Zenith Distance.

The Zenith distance must always have the opposite name to Sun's Bearing at time of observation.

Under Zenith Distance put down declination and apply as follows:

Both same name, add the two.

Different name, subtract less from greater.

Answer will be Latitude.

Name the latitude as follows:

If added, will be named the same as the two of them.

If subtracted, will be named the same as greater of two.

LATITUDE BY SUN.

PROBLEM No. 1.

Jany. 30, 1918. Obs. Mer. Alt. Sun's L. L. 44° 18 South. Dip 36 ft. Long. 91° W.

			00 hrs. 00′
Longitude in time 6 hrs. 04′.			+ 6 hrs. 04′
Declination 17° 44′ 00″ S.		G. T.	30 — 6 hrs. 04′

Altitude	44° 18 00″		
S. D.	+ 16′ 12″		
	44° 34′ 12″	True Alt.	44° 27′ 19″ S
Dip	— 5′ 53″		90° 00′ 00″
	44° 28′ 19″	Zenith Dist.	45° 32′ 41″ N
R. & P.	— 1′	Declination	17° 44′ 00″ S
True Alt.	44° 27′ 19″ S	Lat. (Ans.)	27° 48′ 41″ N

PROBLEM No. 2.

Feby. 1. 1918. Obs. Mer. Alt. Sun's L. L. 78° 05′ 05″ S. Dip 12 ft. Long. 78° 14 E.

			24 hrs. 00′ 00″
Longitude in time 5 hrs. 12′ 56″.			— 5 hrs. 12″ 56″
		Jan. 31st	
		G. T.	18 hrs. 47′ 04″
Declination 17° 18′ 24″ S.			

Altitude	78° 05′ 05″		
S. D.	+ 16′ 12″		
	78° 21′ 17″	True Alt.	78° 17′ 43″ S
Dip.	— 3′ 24″		90° 00′ 00″
	78° 17′ 53″	Zenith Dist.	11° 42′ 17″ N
R. & P.	— 10″	Declination	17° 18′ 24″ S
True Alt.	78° 17′ 43″ S	Latitude	5° 36′ 07″ S

PROBLEM No. 3.

March 20, 1918. Obs. Mer. Alt. Sun's L. L. 89° 37 N. Index Error + 4′ 27″. Dip 18 ft. Long. 111° East. Required Latitude.

			24 hrs. 00′ 00″
Longitude in time 7 hrs. 24′.			7 hrs. 24′ 00″
Declination 0° 29′ 06″ S.		G.T.19 —	16 hrs. 36′ 00″

Altitude	89° 37′ 00″ N		
I. E.	+ 4′ 27″		
	89° 41′ 27″		
S. D.	+ 16′		
	89° 57′ 27″	True Alt.	89° 53′ 18″ N
Dip.	— 4′ 09″		90° 00′ 00″
	89° 53′ 18″	Zenith Dist.	0° 06 42″ S
R. & P.	00	Declination	0° 29′ 06″ S
True Alt.	89° 53′ 18′ N	Latitude	0° 35′ 48″ S

PROBLEM No. 4.

Jany. 1, 1918. Obs. Mer. Alt. Sun's L. L. 59° 59′ 50″ S. Index Error + 50″. Dip. 15 ft. Long. 102° 41 West. Required Latitude?

Longitude in time 6 hrs. 50′ 44″. G. T. 1 — 6 hrs. 50′ 44″ or 7 hrs.

Declination 23° 01′ 42″ S.

Altitude	59° 59′ 50″		
I. E.	+ 50″		
	60° 00′ 40″		
S. D.	+ 16′ 18″		
	60° 16′ 58″	True. Alt.	60° 12′ 40 S
Dip.	— 3′ 48″		90° 00′ 00″
	60° 13′ 10″	Zenith Dist.	29° 47′ 20″ N
R. & P.	— 30″	Declination	23° 01′ 42″ S
True Alt.	60° 12′ 40″ S	Latitude	6° 45′ 38″ N

PROBLEM No. 5.

Jany. 31, 1918. Obs. Mer. Alt. Sun's L. L. 46° 56′ S. Dip 36 ft. Long. 94° West.
Longitude in time 6 hrs. 16′. G. T. 31 — 6 hrs. 16 or 6 hrs.
Declination 17° 27′ 24″ S.

Altitude	46° 56′ 00″ S		
S. D.	+ 16′ 12″		
	47° 12′ 12″	True Alt.	47° 05′ 25″ S
Dip.	— 5′ 53″		90° 00′ 00″
	47° 06′ 19″	Zenith Dist.	42° 54′ 35″ N
R. & P.	— 54″	Declination	17° 27′ 24″ S
True Alt.	47° 05′ 25 S	Latitude	25° 27′ 11″ N

PROBLEM No. 6.

March 21, 1918. Obs. Mer. Alt. Sun's L. L. 57° 21 S. Dip 38 ft. Long. 77° 26 W.

Longitude in time 5 hrs. 10′. G. T. 21 — 5 hrs. 10′ or 5 hrs.
Declination 0° 06′ 30″ N.

Altitude	57° 21′ 00″ S		
S. D.	+ 16′		
	57° 37′ 00″	True Alt.	57° 30′ 25″ S
Dip.	— 6′ 02″		90° 00′ 00″
	57° 30′ 58″	Zenith Dist.	32° 29′ 35″ N
R. & P.	— 33″	Declination	0° 06′ 30″ N
True Alt.	57° 30′ 25″ S	Latitude	32° 36′ 05″ N

PROBLEM No. 7.

Sept. 3, 1918. Obs. Mer. Alt. Sun's L. L. 49° 02′ 15″ S. Dip 28 feet. Long. 118° 15 E.

	24 hrs. 00′ 00″
Longitude in time 7 hrs. 53′.	7 hrs. 53′ 00″
Declination 7° 52′ 54″ N.	G. T. 2 — 16 hrs. 07′ or 16 hrs.

Altitude	49° 02′ 15″ S		
S. D.	+ 15′ 54″		
	49° 18′ 09″	True Alt.	49° 12′ 13″ S
Dip.	— 5′ 11″		90° 00′ 00″
	49° 12′ 58″	Zenith Dist.	40° 47′ 47″ N
R. & P.	— 45″	Declination	7° 52′ 54″ N
True Alt.	49° 12′ 13 S	Latitude	48° 40′ 41″ N

PROBLEM No. 8.

Aug. 8, 1918. Obs. Mer. Alt. Sun's L. L. 38° 16 N. Dip 27 feet. Long. 3° 15 W.
Longitude in time 0 hrs. 13′. G. T. 8 — 0 hrs. 13′ or 0

Declination 16° 18′ 30″ N.

Altitude	38° 16′ 00″ N		
S. D.	+ 15′ 48″		
	38° 31′ 48″	True Alt.	38° 25′ 35″ N
Dip.	— 5′ 06″		90° 00′ 00″
	38° 26′ 42″	Zenith Dist.	51° 34′ 25″ S
R. & P.	— 1′ 07″	Declination	16° 18′ 30″ N
True Alt.	38° 25′ 35″ N	Latitude	35° 15′ 55″ S

PROBLEM No. 9.

July 4, 1918. Obs. Mer. Alt. Sun's L. L. 70° 15 S. Dip 24 ft. Long. 97° 12 W.
Longitude in time 6 hrs 28′ G. T. 4 — 6 hrs. 28′ 48″ or
48″. 6 hrs.

Declination 22° 54′ 42″ N.

Altitude	70° 15′ 00″ S		
S. D.	+ 15′ 42″		
	70° 30′ 42″	True Alt.	70° 25′ 36″ S
Dip.	— 4′ 48″		90° 00′ 00″
	70° 25′ 54″	Zenith Dist.	19° 34′ 24″ N
R. & P.	— 18″	Declination	22° 54′ 42″ N
True Alt.	70° 25′ 36″ S	Latitude	42° 29′ 06″ N

PROBLEM No. 10.

April 18, 1918. Obs. Mer. Alt. Sun's L. L. 41° 02 S. Dip 22 ft. Long. 97° 15 E.

		24 hrs. 00′ 00″
Longitude in time 6 hrs. 29′.		6 hrs. 29′
Declination 10° 32′ 30″ N.	G. T. 17 —	17 hrs. 31′ or 18 hrs.

Altitude	41° 02′ 00″ S		
S. D.	+ 15′ 54″		
	41° 17′ 54″	True Alt.	41° 12′ 19″ S
Dip.	— 4′ 36″		90° 00′ 00″
	41° 13′ 18″	Zenith Dist.	48° 47′ 41″ N
R. & P.	— 59″	Declination	10° 32′ 30″ N
True Alt.	41° 12′ 19″ S	Latitude	59° 20′ 11″ N

PROBLEM No. 11.

Feby. 9, 1918. Obs. Mer. Alt. Sun's L. L. 81° 16 N. Index Error — 3′ 20″. Dip 28 ft. Long. 19° 16 E.

		24 hrs. 00′ 00″
Longitude in time 1 hr. 17′ 04″.		— 1 hr. 17′ 04″
Declination 14° 51′ 20″ S.	G. T. 8 —	22 hrs. 52′ 46″ or 23 hrs.

Altitude	81° 16′ 00″ N		
I. E.	— 3′ 20″		
	81° 12′ 40″		
S. D.	+ 16′ 12″		
	81° 28′ 52″	True Alt.	81° 23′ 34″ N
Dip	— 5′ 11″		90° 00′ 00″
	81° 23′ 41″	Zenith Dist.	8° 36′ 26″ S
R. & P.	— 7″	Declination	14° 51′ 20″ S
True Alt.	81° 23′ 34″ N	Latitude	23° 27′ 46″ S

PROBLEM No. 12.

Oct. 23, 1918. Obs. Mer. Alt. Sun's L. L. 37° 21 S. Index Error + 9′ 16″. Dip 16 ft. Long. 86° 15 W.

Longitude in time 5 hrs. 45′. G. T. 23 — 5 hrs. 45.

Declination 11° 18′ 30″ S.

Altitude	37° 21′ 00″		
I. E.	+ 9′ 16″		
	37° 30′ 16″		
S. D.	+ 16′ 06″		
	37° 46′ 22″	True Alt.	37° 41′ 19″ S
Dip	— 3′ 55″		90° 00′ 00″
	37° 42′ 27″	Zenith Dist.	52° 18′ 41″ N
R. & P.	— 1′ 08″	Declination	11° 18′ 30″ S
True Alt.	37° 41′ 19″ S	Latitude	41° 00′ 11″ N

PROBLEM No. 13.

Oct. 11, 1918. Obs. Mer. Alt. Sun's L. L. 26° 53′ 10″ S. Index Error — 2′ 40″. Dip 17 feet. Long. 18° 02 W.

Longitude in time 1 hr. 12′ 08″. G. T. 11 — 1 hr. 12′ 08″ or 1 hr.

Declination 6° 50′ 15″ S.

Altitude	26° 53′ 10″ S		
I. E.	— 2′ 40″		
	26° 50′ 30″		
S. D.	+ 16′		
	27° 06′ 30″	True Alt.	27° 00′ 34″ S
Dip.	— 4′ 02″		90° 00′ 00″
	27° 02′ 28″	Zenith Dist.	62° 59′ 26″ N
R. & P.	— 1′ 54″	Declination	6° 50′ 15″ S
True Alt.	27° 00′ 34″ S	Latitude	56° 09′ 11″ N

PROBLEM No. 14.

April 3. 1918. Obs. Mer. Alt. Sun's L. L. 60° 22 S. Dip 21 ft. Long. 20° 59 E.

	24 hrs. 00′ 00″
Longitude in time 1 hr. 23′ 56″.	— 1 hr. 23′ 56″
	G. T. 2 — 22 hrs. 36′ 04″
Declination 5° 05 N.	or 23 hrs.

Altitude	60° 22′ 00″ S		
S. D.	+ 16′		
	60° 38′ 00″	True Alt.	60° 33′ 01″ S
Dip.	— 4′ 29″		90° 00′ 00″
	60° 33′ 31″	Zenith Dist.	29° 26′ 59″ N
R. & P.	— 30″	Declination	5° 05′ 00″ N
True Alt.	60° 33′ 01″ S	Latitude	34° 31′ 59″ N

PROBLEM No. 15.

Aug. 30, 1918. Obs. Mer. Alt. Sun's L. L. 57° 18′ 30″ N. Index Error + 45″. Dip 18 feet. Long. 129° 15 W.

Longitude in time 8 hrs. 37′. G. T. 30 — 8 hrs. 37′ or 9 hrs.

Declination 9° 04′ 30″ N.

Altitude	57° 18′ 30″ N		
I. E.	+ 45″		
	57° 19′ 15″		
S. D.	+ 15′ 54″		
	57° 35′ 09″	True Alt.	57° 30′ 27″ N
Dip.	— 4′ 09″		90° 00′ 00″
	57° 31′ 00″	Zenith Dist.	32° 29′ 33″ S
R. & P.	— 33″	Declination	9° 04′ 30″ N
True Alt.	57° 30′ 27″ N	Latitude	23° 25′ 03″ S

PROBLEM No. 16.

Dec. 3, 1918. Obs. Mer. Alt. Sun's L. L. 64° 45′ 15″ N. Index Error — 1′ 10″. Dip 20 ft. Long. 63° 18 E.

Longitude in time 4 hrs. 13′ 12″.

Declination 22° 00′ 36″ S.

	24 hrs. 00′ 00″
	— 4 hrs. 13′ 12″
G. T. 2 —	19 hrs. 46′ 48″ or 20 hrs.

Altitude	64° 45′ 15″ N		
I. E.	— 1′ 10″		
	64° 44′ 05″		
S. D.	+ 16′ 12″		
	65° 00′ 17″	True Alt.	64° 55′ 31″ N
Dip.	— 4′ 23″		90° 00′ 00″
	64° 55′ 54″	Zenith Dist.	25° 04′ 29″ S
R. & P.	— 23″	Declination	22° 00′ 36″ S
True Alt.	64° 55′ 31″ N	Latitude	47° 05′ 05″ S

PROBLEM No. 17.

March 20, 1918. Obs. Mer. Alt. Sun's L. L. 89° 42′ 40″ N. Index Error + 2′ 24″. Dip 20 ft. Long. 101° 30 W.

Longitude in time 6 hrs. 46′. G. T. 20 — 6 hrs. 46′ or 7 hrs.

Declination 0° 15′ 12″ S.

Altitude	89° 42′ 40″ N		
I. E.	+ 2′ 24″		
	89° 45′ 04″	True Alt.	89° 56′ 41″ N
S. D.	+ 16″		90° 00′ 00″
	90° 01′ 04″	Zenith Dist.	0° 03′ 19″ S
Dip.	— 4′ 23″	Declination	0° 15′ 12″ S
True Alt.	89° 56′ 41″ N	Latitude	0° 18′ 31″ S

PROBLEM No. 18.

Sept. 23, 1918. Obs. Mer. Alt. Sun's L. L. 84° 48′ 50″ S. Index Error — 40″. Dip 24 ft. Long. 168° 10 E.

	24 hrs. 00′ 00″
Longitude in time 11 hrs. 12′ 40″.	— 11 hrs. 12′ 40″
	G.T.22 — 12 hrs. 47′ 20″
Declination 0° 19′ 12″ N.	or 13 hrs.

Altitude	84° 48′ 50″		
I. E.	— 40″		
	84° 48′ 10″		
S. D.	+ 15′ 54″		
	85° 04′ 04″	True Alt.	84° 59′ 12″ S
Dip.	— 4′ 48″		90° 00′ 00″
	84° 59′ 16″	Zenith Dist.	5° 00′ 48″ N
R. & P.	— 4″	Declination	0° 19′ 12″ N
True Alt.	84° 59′ 12″ S	Latitude	5° 20′ 00″ N

CHAPTER VII.

LATITUDE BY MERIDIAN ALTITUDE OF STAR.

This example is worked the same as the previous one.

The declination of a star having a very small annual change, it is only necessary to take out the minutes for the month, and the number of degrees on the side opposite the star used.

Declination is found on Page 95 Nautical Almanac.

There is no Semi-Diameter or Parallax for a star, so the meridian altitude is corrected as follows:

Index Error as per sign if any.

Dip (Table 14) subtract.

Refraction (Table 20A) subtract.

Answer will be true altitude.

Subtract true altitude from 90°. Answer will be Zenith Distance, to be named opposite name to star's bearing.

Under Zenith Distance put down declination and apply as follows:

Same names, add

Different names, subtract less from greater.

Answer will be latitude.

Name the latitude as follows:

If added, will be named the same as the two of them.

If subtracted, will be named the same as greater of two.

FINDING TIME OF STARS' MERIDIAN PASSAGE.

From Page 94 (Nautical Almanac) take out Star's Right Ascension for month of example.

From Page 2 (Nautical Almanac) take out Sun's Right Ascension for date given.

Under Star's Right Ascension put down Sun's Right Ascension, and subtract Sun's Right Ascension from Star's Right Ascension.

Answer will be approximate time of Star's Meridian Passage.

If Star's Right Ascension is less than Sun's Right Ascension, add 24 hours to Star's Right Ascension to make the subtraction.

If the answer is less than 12 hours the time is P. M. If more than 12 hours, subtract 12 hours from it and the time will be A. M.

EXAMPLE No. 1.

Jan. 10, 1918. Find the time of Meridian Passage of Star "Spica."

Star's Right Ascension		13 hrs. 20′ 53″
	+	24 hrs.
		37 hrs. 20′ 53″
Sun's Right Ascension		19 hrs. 16′ 47″
		18 hrs. 04′ 06″
	—	12 hrs.
Meridian Passage		6 hrs. 04′ 06″ A. M.

PROBLEM No. 2.

Feby. 16, 1918. Find time of Meridian Passage of Star "Arcturus."

Star's Right Ascension		14 hrs. 11′ 57″
	+	24 hrs.
		38 hrs. 11′ 57″
Sun's Right Ascension		21 hrs. 42′ 40″
		16 hrs. 29′ 17″
	—	12 hrs.
Meridian Passage		4 hrs. 29′ 17″ A. M.

PROBLEM No. 3.

June 3, 1918. Find time of Meridian Passage of Star "Canopus."

Star's Right Ascension	6 hrs. 41′ 33″
Sun's Right Ascension	4 hrs. 44′ 31″
Meridian Passage	1 hr. 37′ 36″ P. M.

PROBLEM No. 4.

May 12, 1918. Find time of Meridian Passage of Star "Sirius."

Star's Right Ascension	6 hrs. 41′ 33″
Sun's Right Ascension	3 hrs. 17′ 47″
Meridian Passage	3 hrs. 23′ 46″ P M.

LATITUDE BY STAR.

PROBLEM No. 1.

Nov. 12, 1918. Obs. Mer. Alt. *Rigel 26° 47′ 10″ S. Index Error — 1′ 24″. Dip 18 ft. Required Latitude?

Declination 8° 17′ 36″ S.

Altitude	26° 47′ 10″ S		
I. E.	— 1′ 24″		
	26° 45′ 46″	True Alt.	26° 39′ 42″ S
Dip	— 4′ 09″		90° 00′ 00″
	26° 41′ 37″	Zenith Dist.	63° 20′ 18″ N
Refr.	— 1′ 55″	Declination	8° 17′ 36″ S
True Alt.	26° 39′ 42″ S	Latitude	55° 02′ 42″ N

PROBLEM No. 2.

Feby. 12, 1918. Obs. Mer. Alt. *Procyon 77° 18′ 10″ S. Index Error + 19″. Dip 16 ft.

Declination 5° 26′ 00″ N.

Altitude	77° 18′ 10″ S		
I. E.	+ 19″		
	77° 18′ 29″	True Alt.	77° 14′ 21″ S
Dip	— 3′ 55″		90° 00′ 00″
	77° 14′ 34″	Zenith Dist.	12° 45′ 39″ N
Refr.	— 13″	Declination	5° 26′ 00″ N
True Alt.	77° 14′ 21″ S	Latitude	18° 11′ 39″ N

PROBLEM No. 3.

March 19, 1918. Obs. Mer. Alt. *Arcturus 36° 10′ 20″ N. Index Error + 2′ 42″. Dip 20 ft.

Declination 19° 36′ 12″ N.

Altitude	36° 10′ 20″ N		
I. E.	+ 2′ 42″		
	36° 13′ 02″	True Alt.	36° 07′ 19″ N
Dip	— 4′ 23″		90° 00′ 00″
	36° 08′ 39″	Zenith Dist.	53° 52′ 41″ S
Refr.	— 1′ 20″	Declination	19° 36′ 12″ N
True Alt.	36° 07′ 19″ N	Latitude	34° 16′ 29″ S

PROBLEM No. 4.

July 9, 1918. Obs. Mer. Alt. *Spica 49° 16′ 25″ S. Dip 18 ft.

Declination 10° 44′ 18″ S.

Altitude	49° 16′ 25″ S	True Alt.	49° 11′ 26″ S
Dip	— 4′ 09″		90° 00′ 00″
	49° 12′ 16″	Zenith Dist.	40° 48′ 34″ N
Refr.	— 50″	Declination	10° 44′ 18″ S
True Alt.	49° 11′ 26″ S	Latitude	30° 04′ 16″ N

PROBLEM No. 5.

March 11, 1918. Obs. Mer. Alt. *Betelgeux 80° 10′ 20″ N. Dip 30 ft.

Declination 7° 23′ 30″ N.

Altitude	80° 10′ 20″ N	True Alt.	80° 04′ 48″ N
Dip	— 5′ 22″		90° 00′ 00″
	80° 04′ 58″	Zenith Dist.	9° 55′ 12″ S
Refr.	— 10″	Declination	7° 23′ 30″ N
True Alt.	80° 04′ 48″ N	Latitude	2° 31′ 42″ S

PROBLEM No. 6.

Feby. 16, 1918. Obs. Mer. Alt. *Aldebaran 38° 15′ S. Dip 28 ft.

Declination 16° 20′ 48″ N.

Altitude	38° 15′ 00″ S	True Alt.	38° 08′ 35″ S
Dip	— 5′ 11″		90° 00′ 00″
	38° 09′ 49″	Zenith Dist.	51° 51′ 25″ N
Refr.	— 1′ 14″	Declination	16° 20′ 48″ N
True Alt.	38° 08′ 35″ S	Latitude	68° 12′ 13″ N

PROBLEM No. 7.

Nov. 21, 1918. Obs. Mer. Alt. *Sirius 41° 16′ 00″ S. Dip 40 ft.

Declination 16° 36′ 06″ S

Altitude	41° 16′ 00″ S	True Alt.	41° 08′ 41″ S
Dip	— 6′ 12″		90° 00′ 00″
	41° 09′ 48″	Zenith Dist.	48° 51′ 19″ N
Refr.	— 1′ 07″	Declination	16° 36′ 06″ S
True Alt.	41° 08′ 41″ S	Latitude	32° 15′ 13″ N

PROBLEM No. 8.

April 6, 1918. Obs. Mer. Alt. *Fomalhaut 18° 17′ 00″ S. Dip 28 ft.

Declination 30° 03′ 18″ S.

Altitude	18° 17′ 00″ S	True Alt.	18° 08′ 54″ S
Dip	— 5′ 11″		90° 00′ 00″
	18° 11′ 49″	Zenith Dist.	71° 51′ 06″ N
Refr.	— 2′ 55″	Declination	30° 03′ 18″ S
True Alt.	18° 08′ 54″ S	Latitude	41° 47′ 48″ N

PROBLEM No. 9.

May 12, 1918. Obs. Mer. Alt. *Antares 80° 16′ 00″ N. Dip 20 ft.

Declination 26° 15′ 12″ S.

Altitude	80° 16′ 00″ N	True Alt.	80° 11′ 27″ N
Dip	— 4′ 23″		90° 00′ 00″
	80° 11′ 37″	Zenith Dist.	9° 48′ 33″ S
Refr.	— 10″	Declination	26° 15′ 12″ S
True Alt.	80° 11′ 27″ N	Latitude	36° 03′ 45″ S

PROBLEM No. 10.

July 16, 1918. Obs. Mer. Alt. *Fomalhaut 73° 36′ 0″ S. Index Error + 1′ 40″. Dip 24 ft.

Declination 30° 03′ 00″ S.

Altitude	73° 36′ 00″ S		
I. E.	+ 1′ 40″		
	73° 37′ 40″	True Alt.	73° 32′ 34″ S
Dip	— 4′ 48″		90° 00′ 00″
	73° 32′ 52″	Zenith Dist.	16° 27′ 26″ N
Refr.	— 18″	Declination	30° 03′ 00″ S
True Alt.	73° 32′ 34″ S	Latitude	13° 35′ 34″ S

PROBLEM No. 11.

April 6, 1918. Obs. Mer. Alt. *Regulus 50° 14′ 20″ S. Index Error + 1′ 15″. Dip 18 ft.

Declination 12° 21′ 54″ N.

Altitude	50° 14′ 20″ S		
I. E.	+ 1′ 15″		
	50° 15′ 35″	True Alt.	50° 10′ 37″ S
Dip	— 4′ 09″		90° 00′ 00″
	50° 11′ 26″	Zenith Dist.	39° 49′ 23″ N
Refr.	— 49″	Declination	12° 21′ 54″ N
True Alt.	50° 10′ 37″ S	Latitude	52° 11′ 17″ N

PROBLEM No. 12.

Dec. 26, 1918. Obs. Mer. Alt. *Sirius 36° 28′ 30″ S. Index Error — 45″. Dip 16 ft.

Declination 16° 36′ 18″ S.

Altitude	36° 28′ 30″ S		
I. E.	— 45″		
	36° 27′ 45″	True Alt.	36° 22′ 31″ S
Dip	— 3′ 55″		90° 00′ 00″
	36° 23′ 50″	Zenith Dist.	53° 37′ 29″ N
Refr.	— 1′ 19″	Declination	16° 36 18″ S
True Alt.	36° 22′ 31″ S	Latitude	37° 01′ 11″ N

CHAPTER VIII.

LONGITUDE BY SUN.

The longitude of a place is the number of hours, minutes and seconds East or West of the meridian of Greenwich, which is Long. 0°, expressed in degrees, minutes and seconds.

A chronometer is an ordinary clock of the finest make, with a 12 hour face, and keeps the time of Greenwich.

The astronomical day is explained under definitions, and begins at noon and ends at noon.

In all instances in this example if Chronometer time is A. M. add 12 to the hours and date one day back.

P. M. chronometer time keeps same date as example.

Put down chronometer time and correct fast or slow as given. Answer will be Mean Time Greenwich, expressed M. T. G.

Take out Sun's declination for Greenwich date and time.

The Polar Distance is the angular distance of a heavenly body from the pole nearest the observer. To find Polar Distance follow rule:

If Latitude and Declination are different names, add 90° to Declination.

If Latitude and Declination are same names, subtract Declination from 90°.

A chronometer always keeps the time of a day of exactly 24 hours, which is called a Mean Day, but the sun's time which is known as Apparent Time, changes a little every day. The difference between Mean Time and Apparent Time is called the Equation of Time.

Take from the Almanac Equation of Time for Greenwich date and time, and apply it to M. T. G. as by sign given in almanac.

Answer will be Apparent Time Greenwich, expressed A. T. G.

Correct observed altitude of sun as follows:

Index Error as per sign if any.

Semi-Diameter from Almanac. Add for Lower Limb. Subtract for Upper.

Dip (Table 14) subtract.

Refraction and Parallax (Table 20B) subtract.

Answer will be true altitude.

Add together true altitude, latitude and polar distance, and divide sum by 2. Answer will be Half Sum.

Subtract true altitude from Half Sum. Answer will be Remainder.

From Table 44 (Bowditch) take out the following Logs, to the nearest minute of arc, will be close enough for practical purposes:

Secant of Latitude. Rejecting 10 from index number.

Cosecant of Polar Distance. Rejecting 10 from index number. (See note.)

Cosine of Half Sum.

Sine of Remainder.

Add these four logs together, and subtract 10 from index number.

(Note) If Polar distance exceeds 90° take Secant of declination instead.

Log Haversine (Table 45) that agrees with sum of Logs will be the Apparent Time Ship, expressed A. T. S.

If sight was taken in A. M. read hours and minutes from bottom, and seconds in right hand column, and date 1 day back.

If sight was taken in P. M. read hours and minutes from top, and seconds in left hand column, and date same as example.

Under A. T. S. put down A. T. G. If both are same date subtract less from greater, if different dates add 24 hours to greatest date, and then subtract less from greater. Answer will be longitude in time.

Multiply hours of longitude in time by 60, and add the minutes. Divide the minutes by 4, and the result will be degrees of longitude. If any minutes are left multiply by 60 and add the seconds, divide by 4, and the result will be minutes of longitude. If any seconds are left multiply by 60 and divide by 4, and the result will be seconds of longitude.

If the Greenwich time is best, the longitude is West.
If the Greenwich time is least, the longitude is East.

FINDING GREENWICH DATE AND TIME.

The Greenwich time and date is absolutely necessary to be found correctly in this example.

In the problems given in this book the reading of the chronometer is given A. M. or P. M. and others longitude by dead reckoning is given; in some of them the Greenwich date and time is given.

Below will be found the different methods that an example may be given, and the explanation of how the Greenwich date may be found.

If the chronometer reads A. M. and no longitude by Dead Reckoning is given, add 12 hours to the time, and date one day back.

For Example:

Jany. 25th P. M. at ship, Chron, read 10 hrs. 16′ 28″ A. M.

Greenwich date and time will be Jany. 24th, 22 hrs. 16′ 28″.

If chronometer reads P. M. and no longitude by dead reckoning is given, the Greenwich date and time will be the same as the example.

For Example: Jany. 25th A. M. at ship. Chron. read 1 hr. 16′ 28″ P. M.

Greenwich date and time will be Jany. 25th 1 hr. 16′ 28″.

If the Greenwich date is given, the chronometer is put down in the following manner:

Jany. 25th A. M. at ship. Chron. read Jany. 24th 11 hrs. 16′ 28″.

Greenwich date and time will be Jany. 24th 11 hrs. 16′ 28″.

If the approximate ship's time and Long. by D. R. are given in an example, and the chronometer reading without stating whether it is A. M. or P. M. the student must be able to determine whether the chronometer is A. M. or P. M. in order to convert it into astronomical time.

For example, if problem was given in following manner:

Jany. 26th about 7 A. M. at ship, Long. by D. R. 90 degrees West, Chron. read 1 hr. 10′.

Now as the difference between ship's time and Greenwich time is the longitude in time, we have for the above example a longitude in time of 6 hours.

In West longitude the Greenwich time is the largest. So if it is about 7 A. M. at ship, it must be 1 hr. 10′ P. M. at Greenwich. Or, Greenwich date Jany. 26, 1 hr. 10′.

Now presuming this example was in Long. by D. R. 90 degrees East.

In East longitude the ship's time is the largest. So if it is about 7 A. M. at ship, it must be 1 hr. 10′ A. M. at Greenwich. Or Greenwich date, Jany. 25th, 13 hrs. 10′.

This will explain practically all the methods of finding Greenwich date, and if the student will read his problem carefully he should have no trouble.

It must always be remembered that the astronomical day begins at noon of civil day, and ends at noon, and a 24 hour face clock must be imagined.

PROBLEM No. 1.

Jany. 31, 1918. A. M. Obs. Alt. Sun's L. L. 13° 54′ 00″. Dip 36 ft. Chron. read 2 hrs. 46′ 17″ P. M., fast 34′ 34″. Lat. 25° 44 N.

Chron.	2 hrs. 46′ 17″		
fast	— 34′ 34″		
M. T. G. 31	— 2 hrs. 11′ 43″	Declination	17° 30′ 12″ S
Eq. T.	— 13′ 32″		90° 00′ 00″
A. T. G. 31	— 1 hr. 58′ 11″	Polar Dist.	107° 30′ 12″

Altitude	13° 54′ 00″		
S. D.	+ 16′ 15″		
	14° 10′ 15″		
Dip	— 5′ 53″		
	14° 04′ 22″		
R. & P.	— 3′ 40″		
True Alt.	14° 00′ 42″		
Lat.	25° 44	Secant	.04536
P. D.	107° 30′ 12″	Cosecant	.02058
	2(147° 14′ 54″		
Half Sum	73° 37′ 27″	Cosine	9.45035
True Alt.	14° 00′ 42″		
Remainder	59° 36′ 45″	Sine	9.93584
		Log Haversine	9.45213

A. T. S.	30 — 19 hrs. 42′ 46″
A. T. G.	30 — 25 hrs. 58′ 11″
Long. in Time	6 hrs. 15′ 25″
	4(375′ 205″ 60
Long.	93° 51′ 15″ W

PROBLEM No. 2.

Jany. 30, 1918. P. M. Obs. Alt. Sun's L. L. 18° 32. Dip 36 ft. Chron. read 10 hrs. 42′ 46″ P. M., fast 34′ 28″. Lat. 27° 12 N.

Chron.	10 hrs. 42′ 46″		
fast	— 34′ 28″		
M.T.G.30 —	10 hrs. 08′ 18″	Declination	17° 41′ 18″ S
Eq. T.	— 13′ 26″		90° 00′ 00″
A. T. G. 30 —	9 hrs. 54′ 52″	Polar Dist.	107° 41′ 18″

Altitude	18° 32′ 00″		
S. D.	+ 16′ 15″		
	18° 48′ 15″		
Dip	— 5′ 53″		
	18° 42′ 22°		
R. & P.	— 2′ 43″		
True Alt.	18° 39′ 39″		
Lat.	27° 12	Secant	.05089
Pol. Dist.	107° 41′ 18″	Cosecant	.02102
	2(153° 32′ 57″		
Half Sum	76° 46′ 28″	Cosine	9.35968
True Alt.	18° 39′ 39″		
Remainder	58° 06′ 49″	Sine	9.92897
		Log Haversine	9.36056

A. T. S.	30 — 3 hrs. 48′ 56″
A. T. G.	30 — 9 hrs. 54′ 52″
Long. in Time	6 hrs. 05′ 56″
	4(365 116″
Long.	91° 29 W

PROBLEM No. 3.

March 10, 1918. A. M. Obs. Alt. Sun's L. L. 28° 13′ 00″. Dip 38 ft. Chron. read 3 hrs. 12′ 15″ A. M. Lat. 31° 46 S.

M. T. G. 9 — 15 hrs.	12′ 15″	Declination	4° 27′ 30″ S
Eq. T. —	10′ 39″		90° 00′ 00″
A. T. G. 9 — 15 hrs.	01′ 36″	Polar Dist.	85° 32′ 30″

Altitude	28° 13′ 00″		
S. D.	+ 16′ 08″		
	28° 29′ 08″		
Dip	— 6′ 02″		
	28 23′ 06″		
R. & P.	— 1′ 40″		
True Alt.	28° 21′ 26″		
Lat.	31° 46	Secant	.07048
Pol. Dist.	85° 32′ 30″	Cosecant	.00132
	2(145° 39′ 56″		
Half Sum	72° 49′ 58″	Cosine	9.47005
True Alt.	28° 21′ 26″		
Remainder	44° 28′ 32″	Sine	9.84553
		Log Haversine	9.38738

A. T. S.	9 — 20 hrs. 03′ 12″
A. T. G.	9 — 15 hrs. 01′ 36″
Long. in Time	5 hrs. 01′ 36″

Long. 75° 24 East.

PROBLEM No. 4.

Jany. 30, 1918. P. M. Obs. Alt. Sun's L. L. 18° 32. Dip 36 ft. Chron. read 10 hrs. 42′ 46″ A. M., fast 34′ 28″. Lat. 27° 12 N.

Chron.	22 hrs. 42′ 46″		
fast	— 34′ 28″		
M.T.G. 29 —	22 hrs. 08′ 18″	Declination	17° 49′ 24″ S
Eq. T.	— 13′ 21″		90° 00′ 00″
A.T.G. 29 —	21 hrs. 54′ 57″	Polar Dist.	107° 49′ 24″

Altitude	18° 32		
S. D.	+ 16′ 16″		
	18° 48′ 16″		
Dip	— 5′ 53″		
	18° 42′ 23″		
R. & P.	— 2′ 43″		
True Alt.	18° 39′ 40″		
Lat.	27° 12	Secant	.05089
Pol. Dist.	107° 49′ 24″	Cosecant	.02134
	2(153° 41′ 04″		
Half Sum	76° 50′ 32″	Cosine	9.35698
True Alt.	18° 39′ 40″		
Remainder	58° 10′ 52″	Sine	9.92929
		Log Haversine	9.35850

A. T. S.	29 — 27 hrs. 48′ 20″
A. T. G.	29 — 21 hrs. 54′ 57″
Long. in Time	5 hrs. 53′ 23″

Long. 88° 20′ 45″ East.

PROBLEM No. 5.

March 10, 1918. A. M. Obs. Alt. Sun's L. L. 21° 00′ 00″. Dip. 38 ft. Chron. read 1 hr. 07′ 56″ P. M. Lat. 31° 19 N.

M.T.G. 10 — 1 hr. 07′ 56″		Declination	4° 17′ 42″ S
Eq. T. — 10′ 33″			90° 00′ 00″
A.T.G. 10 — 0 hrs. 57′ 23″		Polar Dist.	94° 17′ 42″

Altitude	21° 00′ 00″		
S. D.	+ 16′ 08″		
	21° 16′ 08″		
Dip	— 6′ 02″		
	21° 10′ 06″		
R. & P.	— 2′ 21″		
True Alt.	21° 07′ 45″		
Lat.	31° 19	Secant	.06839
Polar Dist.	94° 17′ 42″	Cosecant.	.00122
	2(146° 44′ 27″		
Half Sum	73° 22′ 13″	Cosine	9.45674
True Alt.	21° 07′ 45″		
Remainder	52° 14′ 28″	Sine	9.89791
		Log Haversine	9.42426

A. T. S.	9 — 19 hrs. 51′ 49″
A. T. G.	9 — 24 hrs. 57′ 23″
Long. in Time	5 hrs. 05′ 34″

Long. 76° 23′ 30″ W.

PROBLEM No. 6.

July 10, 1918. A. M. Obs. Alt. Sun's L. L. 18° 15. Dip 38 ft. Chron. read 10 hrs. 15′ 25″ A. M., slow 12′ 10″. Lat. 37° 15 N.

Chron.	22 hrs. 15′ 25″		
slow	+ 12′ 10″		
M. T. G. 9 —	22 hrs. 27′ 35″	Declination	22° 19′ 36″ N
Eq. T.	— 5′ 02″		90° 00′ 00″
A.T.G. 9 —	22 hrs. 22′ 33″	Polar Dist.	67° 40′ 24″

Altitude	18° 15′ 00″		
S. D.	+ 15′ 45″		
	18° 30′ 45″		
Dip	— 6′ 02″		
	18° 24′ 43″		
R. & P.	— 2′ 53″		
True Alt.	18° 21′ 50″		
Lat.	37° 15	Secant	.09909
Polar Dist.	67° 40′ 24″	Cosecant	.03386
	2(123° 17′ 14″		
Half Sum	61° 38′ 37″	Cosine	9.67656
True Alt.	18° 21′ 50″		
Remainder	43° 16′ 47″	Sine	9.83608
		Log Haversine	9.64559

A. T. S.	9 — 18 hrs. 26′ 34″
A. T. G.	9 — 22 hrs. 22′ 33″
Long. in Time	3 hrs. 55′ 59″

Long. 58° 59′ 45″ West.

PROBLEM No. 7.

July 16, 1918. A. M. Obs. Alt. Sun's L. L. 14° 28′ 32″. Dip. 21 ft. Chron. read 4 hrs. 16′ 28″ A. M., slow 14′ 28″. Lat. 26° 33 N.

Chron.	16 hrs. 16′ 28″		
slow	+ 14′ 28″		
M.T.G. 15 — 16 hrs. 30′ 56″		Declination	21° 31 N
Eq. T.	— 5′ 46″		90° 00
A.T.G. 15 — 16 hrs. 25′ 10″		Polar Dist.	68° 29

Altitude	14° 28′ 32″		
S. D.	+ 15′ 45″		
	14° 44′ 17″		
Dip	— 4′ 29″		
	14° 39′ 48″		
R. & P.	— 3′ 30″		
True Alt.	14° 36′ 18″		
Lat.	26° 33	Secant	.04840
Polar Dist.	68° 29	Cosecant	.03137
	2(109° 38′ 18″		
Half Sum	54° 49′ 09″	Cosine	9.76057
True Alt.	14° 36′ 18″		
Remainder	40° 12′ 51″	Sine	9.81002
		Log Haversine	9.65036

A. T. S.	15 — 18 hrs. 24′ 19″
A. T. G.	15 — 16 hrs. 25′ 10″
Long. in Time	1 hr. 59′ 09″

Long. 29° 47′ 15″ East.

PROBLEM No. 8.

Jany. 31, 1918. P. M. Obs. Alt. Sun's L. L. 23° 16. Dip 36 ft. Chron. read 10 hrs. 38′ 38″ P. M., fast 34′ 37″. Lat. 24° 55 N.

Chron.	10 hrs. 38′ 38″		
fast	— 34′ 37″		
M.T.G. 31 —	10 hrs. 04′ 01″	Declination	17° 24′ 42″ S
Eq. T.	— 13′ 35″		90° 00′ 00″
A.T.G. 31 —	9 hrs. 50′ 26″	Polar Dist.	107° 24′ 42″

Altitude	23° 16′ 00″		
S. D.	+ 16′ 16″		
	23° 32′ 16″		
Dip	— 5′ 53″		
	23° 26′ 23″		
R. & P.	— 2′ 14″		
True Alt.	23° 24′ 09″		
Lat.	24° 55	Secant	.04243
Polar Dist.	107° 24′ 42″	Cosecant	.02038
	2(155° 43′ 51″		
Half Sum	77° 51′ 55″	Cosine	9.32261
True Alt.	23° 24′ 09″		
Remainder	54° 27′ 46″	Sine	9.91051
		Log Haversine	9.29593

A. T. S.	31 — 3 hrs. 31′ 11″
A. T. G.	31 — 9 hrs. 50′ 26″
Long in Time	6 hrs. 19′ 15″

Long. 94° 48′ 45″ West.

PROBLEM No. 9.

Dec. 3, 1918. A. M. Obs. Alt. Sun's L. L. 28° 16′ 15″. Dip 40 ft. Chron. read 4 hrs. 16′ 28″ P. M., slow 14′ 28″. Lat. 26° 33 S.

Chron.	4 hrs. 16′ 28″		
slow	+ 14′ 28″		
M.T.G. 3	— 4 hrs. 30′ 56″	Declination	22° 03′ 42″ S
Eq. T.	+ 10′ 16″		90° 00′ 00″
A.T.G. 3	— 4 hrs. 41′ 12″	Polar Dist.	67° 56′ 12″

Altitude	28° 16′ 15″		
S. D.	+ 16′ 12″		
	28° 32′ 27″		
Dip	— 6′ 12″		
	28° 26′ 15″		
R. & P.	— 1′ 40″		
True Alt.	28° 24′ 35″		
Lat.	26° 33	Secant	.04840
Polar Dist.	67° 56′ 12″	Cosecant	.03304
	2(122° 53′ 53″		
Half Sum	61° 26′ 56″	Cosine	9.67936
True Alt.	28° 24′ 35″		
Remainder	33° 02′ 21″	Sine	9.73650
		Log Haversine	9.49730

A. T. S.	2 — 19 hrs. 27′ 13″
A. T. G.	2 — 28 hrs. 41′ 12″
Long. in Time	9 hrs. 13′ 59″

Long. 138° 29′ 45″ West.

PROBLEM No. 10.

Oct. 16, 1918. A. M. Obs. Alt. Sun's L. L. 18° 26′ 15″. Dip 40 ft. Chron. read 2 hrs. 08′ 03′ A. M., fast 58′ 13″. Lat. 3° 21 S.

Chron.	14 hrs. 08′ 03″			
fast	— 58′ 13″			
M.T.G. 15 —	13 hrs. 09′ 50″	Declination	8° 31′ 18″ S	
Eq. T.	+ 14′ 08″		90° 00′ 00″	
A.T.G. 15 —	13 hrs. 23′ 58″	Polar Dist.	81° 28′ 42″	

Altitude	18° 26′ 15″		
S. D.	+ 16′ 06″		
	18° 42′ 21″		
Dip	— 6′ 12″		
	18° 36′ 09″		
R. & P.	— 2′ 51″		
True Alt.	18° 33′ 18″		
Lat.	3° 21	Secant	.00074
Polar Dist.	81° 28′ 42″	Cosecant	.00482
	2(103° 23′ 00″		
Half Sum	51° 41′ 30	Cosine	9.79232
True Alt.	18° 33′ 18″		
Remainder	33° 08′ 12″	Sine	9.73766
		Log Haversine	9.53554

A. T. S	15 — 19 hrs. 13′ 07″
A. T. G.	15 — 13 hrs. 23′ 58″
Long. in Time	5 hrs. 49′ 09″

Long. 87° 17′ 15″ East.

CHAPTER IX.

NOON POSITION SIGHTS.

The following problems are worked the same as the foregoing longitude sights as far as obtaining the longitude at sight.

In working a sight for longitude the correct latitude of the place at time of sight must be used.

In this problem the latitude at noon is given, and the latitude at sight must be found by taking from Table 2 (Bowditch) the difference of latitude and departure for the course and distance sailed between sight and noon.

If the sight is taken in A. M. the name of the latitude difference North or South must be reversed to work the latitude back to sight.

If taken in P. M. the name of the latitude difference stays the same.

By applying the difference of latitude to latitude at noon, will be found the latitude at sight, which is the latitude to be used in working the problem.

The middle latitude is then found by adding together latitude at noon and latitude at sight, and dividing sum by 2.

Enter Table 2 with middle latitude as a course and look for departure in latitude column. In the distance column opposite will be difference of longitude in miles.

If sight is taken in P. M. the name of the difference of longitude East or West must be reversed to work the problem back to noon.

If sight is A. M. the name of the difference of longitude stays the same.

The chronometer is corrected for the original error slow or fast, and the number of days and tenths of a day from date of original error to Greenwich date are figured out, and multiplied by daily rate, this will give the accumulated rate.

This accumulated rate is then applied to chronometer, and the result will be M. T. G.

The example is then worked as in previous problem, and the longitude at sight is obtained.

By applying the difference of longitude to the longitude at sight, will give the longitude at noon.

This will give ship's noon position.

LONGITUDE BY SUN TO FIND NOON POSITION.

PROBLEM No. 1. (See Illustration).

Feby. 10, 1918. A. M. Obs. Alt. Sun's L. L. 9° 09′ 50″. Index Error — 3′ 20″. Dip 18 ft. Chron. read Feby. 9th 9 hrs. 59′ 25″ which was fast on Jany. 10 th 34′ 12″ and losing 10″.8 daily. Lat. at Noon 50° 16′ 24″ N. Ship run from sight to noon S 56° W (true) 38 miles.

Chron.	9 hrs. 59′ 25″	30.4 days	
fast	— 34′ 12″	10″.8	
	9 hrs. 25′ 13″	328″ Acc. rate	
Acc. rate	+ 5′ 28″		
M.T.G. 9 —	9 hrs. 30′ 41″	Lat. at Noon	50° 16′ 24″ N
Eq. T.	— 14′ 22″	Diff. Lat.	21′ 06″ N
A.T.G. 9 —	9 hrs. 16′ 19″	Lat. at sight	50° 37′ 30″ N
Declination	14° 42′ 48″ S	Departure	31.6
	90° 00′ 00″	Diff. Long.	49′ W
Polar Dist.	104° 42′ 48″		

Altitude	9° 09′ 50″		
I. E.	— 3′ 20″		
	9° 06′ 30″		
S. D.	+ 16′ 12″		
	9° 22′ 42″		
Dip	— 4′ 09″		
	9° 18′ 33″		
R. & P.	— 5′ 34″		
True Alt.	9° 12′ 59″		
Lat.	50° 37′ 30	Secant	.19764
Polar Dist.	104° 42′ 48″	Cosecant	.01449
	2(164° 33′ 17″		
Half Sum	82° 16′ 38″	Cosine	9.12799
True Alt.	9° 12′ 59″		
Remainder	73° 03′ 39″	Sine	9.98075
		Log Haversine	9.32087

A.T.S. 9 —	20 hrs. 22′ 10″	Long. at sight	166° 27′ 45″ E
A.T.G. 9 —	9 hrs. 16′ 19″	Diff. Long.	49′ 00″ W
Long. in T.	11 hrs. 05′ 51″	Long. at Noon	165° 38′ 45 E

PROBLEM No. 2.

Jany. 31, 1918. A. M. Obs. Alt. Sun's L. L. 15° 08. Dip 36 ft. Chron. read 2 hrs. 45′ 49″ P. M. which was fast on Jany. 11th 31′ 34″ and gaining 9″ daily. Lat. at Noon 25° 31′ 17 N. Ship run from sight to noon S 26 W 57 miles.

Chron.	2 hrs. 45′ 49″	20.1 days	
fast	— 31′ 34″	9″	
	2 hrs. 14′ 15″	180.9″ Acc. rate	
Acc. rate	— 3′ 01″		
M.T.G. 31 —	2 hrs. 11′ 14″	Lat. Noon	25° 31′ 17″ N
Eq. T.	— 13′ 32″	Diff. Lat.	51′ 12″ N
A.T.G. 31 —	1 hr. 57′ 42″	Lat. at sight	26° 22′ 29″ N

Declination	17° 30′ 12″ S		Departure 25.0
	90° 00′ 00″		Diff. Long. 28′ W
Polar Dist.	107° 30′ 12″		

Altitude	15° 08		
S. D.	+ 16′ 16″		
	15° 24′ 16″		
Dip	— 5′ 53″		
	15° 18′ 23″		
R. & P.	— 3′ 21″		
True Alt.	15° 15′ 02″		
Lat.	26° 22′ 29″	Secant	.04771
Polar Dist.	107° 30′ 12″	Cosecant	.02058
	2(149° 07′ 43″		
Half Sum	74° 33′ 51″	Cosine	9.42507
True Alt.	15° 15′ 02″		
Remainder	59° 18′ 49″	Sine	9.93450
		Log Haversine	9.42786

A.T.G. 30 —	25 hrs. 57′ 42″	Long. at sight	91° 45′ 30″ W
A.T.S. 30 —	19 hrs. 50′ 40″	Diff. Long.	28′ 00″ W
Long. in T.	6 hrs. 07′ 02″	Long. at Noon	92° 13′ 30″ W

PROBLEM No. 3.

Jany. 2, 1918. A. M. Obs. Alt. Sun's L. L. 49° 10. Index Error — 2′ 40″. Dip 14 ft. Chron. read 7 hrs. 08′ 50″ A. M. which was slow on Dec. 7th 19′ 10″.6 and losing 9″.8 daily. Lat. at Noon 37° 21′ 36″ S. Ship run from sight to noon S 45° W (true) 32 miles.

Chron.	19 hrs. 08′ 50″		25.8 days
slow	+ 19′ 10″		9″.8
	19 hrs. 28′ 00″		253″ Acc. rate
Acc rate	+ 4′ 13″		
		Lat. at Noon	37° 21′ 36″ S
M.T.G. 1 —	19 hrs. 32′ 13″	Diff. Lat.	22′ 36″ N
Eq. T.	— 3′ 49″		
		Lat. at sight	36° 59′ 00″ S
A.T.G. 1 —	19 hrs. 28′ 24″		

Declination	22° 59 S	Departure	22.6
	90° 00	Diff. Long.	28′ W
Polar Dist.	67° 01		

Altitude	49° 10		
I. E.	— 2′ 40″		
	49° 07′ 20″		
S. D.	+ 16′ 18″		
	49° 23′ 38″		
Dip	— 3′ 40″		
	49° 19′ 58″		
R. & P.	— 45″		
True Alt.	49° 19′ 13″		
Lat.	36° 59	Secant	.09756
Pol. Dist.	67° 01	Cosecant	.03592
	2(153° 19′ 13″		
Half Sum	76° 39′ 36″	Cosine	9.36289
True Alt.	49° 19′ 13″		
Remainder	27° 20′ 23″	Sine	9.66197
		Log Haversine	9.15834

A.T.S. 1 —	21 hrs. 01′ 36″	Long. at sight	23° 18 E
A.T.G. 1 —	19 hrs. 28′ 24″	Diff. Long.	28 W
Long. Time	1 hr. 33′ 12″	Long. at Noon	22° 50 E

PROBLEM No. 4.

Oct. 17, 1918. P. M. Obs. Alt. Sun's L. L. 16° 19′ 15″. Dip 28 ft. Chron. read 11 hrs. 55′ 03″ P. M. which was fast on Sept. 23d 8′ 23″ and gaining 8″.2 daily. Lat. at Noon 22° 35′ 48″ S. Ship run from noon to sight N 18° W 42 miles.

Chron.	11 hrs. 55′ 03″		24.5 days
fast	— 8′ 23″		8″.2
	11 hrs. 46′ 40″		201″ Acc. rate
Acc. rate	— 3′ 21″		
		Lat. at Noon	22° 35′ 48″ S
M.T.G. 17 —	11 hrs. 43′ 19″	Diff. Lat.	39′ 54″ N
Eq. T.	+ 14′ 33″		
		Lat. at sight	21° 55′ 54″ S
A.T.G. 17 —	11 hrs. 57′ 52″		
Declination	9° 14′ 30″ S	Departure	13.0
	90° 00′ 00″	Diff. Lon.	14′ E
Polar Dist.	80° 45′ 30″		

Altitude	16° 19′ 15″		
S. D.	+ 16′ 06″		
	16° 35′ 21″		
Dip	— 5′ 11″		
	16° 30′ 10″		
R. & P.	— 3′ 06″		
True Alt.	16° 27′ 04″		
Lat.	21° 55′ 54″	Secant	.03263
Pol. Dist.	80° 45′ 30″	Cosecant	.00567
	2(119° 08′ 28″		
Half Sum	59° 34′ 14″	Cosine	9.70461
True Alt.	16° 27′ 04″		
Remainder	43° 07′ 10″	Sine	9.83473
		Log Haversine	9.57764

A.T.S. 17 —	5 hrs. 03′ 34″	Long. at sight	103° 34′ 30″ W
A.T.G. 17 —	11 hrs. 57′ 52″	Diff. Long.	14′ E
Long. in T.	6 hrs. 54′ 18″	Long. at Noon	103° 20′ 30″ W

PROBLEM No. 5.

Dec. 1, 1918. A. M. Obs. Alt. Sun's L. L. 15° 18′ 12″. Dip 26 ft. Chron. read Nov. 30th 9 hrs. 02′ 05″ which was slow on Nov. 10th 3′ 55″ and gains 7″.8 daily. Lat. at Noon 18° 16 N. Ship run from sight to noon N 28° E (true) 58 miles.

Chron.	9 hrs. 02′ 05″		20.4 days
slow	+ 3′ 55″		7″.8
	9 hrs. 06′ 00″		159″ Acc. rate
Acc. rate	— 2′ 39″		
		Lat. at Noon	18° 16′ 00″ N
M.T.G. 30 —	9 hrs. 03′ 21″	Diff. Lat.	51′ 12″ S
Eq. T.	+ 11′ 20″		
		Lat. at sight	17° 24′ 48″ N
A.T.G. 30 —	9 hrs. 14′ 41″		
Declination	21° 37′ 45″ S	Departure	27.2
	90° 00′ 00″	Diff. Long.	28′ 30″ E
Polar Dist.	111° 37′ 45″		

Altitude	15° 18′ 12″		
S. D.	+ 16′ 12″		
	15° 34′ 24″		
Dip	— 5′		
	15° 29′ 24″		
R. & P.	— 3′ 19″		
True Alt.	15° 26′ 05″		
Lat.	17° 24′ 48″	Secant	.02038
Pol. Dist.	111° 37′ 45″	Cosecant	.03172
	2(144° 28′ 38″		
Half Sum	72° 14′ 19″	Cosine	9.48450
True Alt.	15° 26′ 05″		
Remainder	56° 48′ 14″	Sine	9.92260
		Log Haversine	9.45920

A.T.S. 30 —	19 hrs. 40′ 25″	Long. at sight	156° 26′ 00″ E
A.T.G. 30 —	9 hrs. 14′ 41″	Diff. Long.	28′ 30″ E
Long. in T.	10 hrs. 25′ 44″	Long. at Noon	156° 54′ 30″ E

PROBLEM No. 6.

May 3, 1918. A. M. Obs. Alt. Sun's L. L. 28° 49. Dip 30 ft. Chron. read 8 hrs. 03′ 02″ A. M. which was slow on April 7th 3′ 28″ and gaining 2″.8 daily. Lat. at noon 28° 16′ 28″ N. Ship run from sight to noon S 69° W 73 miles.

Chron.	20 hrs. 03′ 02″		25.8 days
slow	+ 3′ 28″		2″.8
	20 hrs. 06′ 30″		72″ Acc. rate
Acc. rate	— 1′ 12″		
M.T.G. 2 —	20 hrs. 05′ 18″	Lat. at Noon	28° 16′ 28″ N
Eq. T.	+ 3′ 09″	Diff. Lat.	26′ 12″ N
A.T.G. 2 —	20 hrs. 08′ 27″	Lat. at sight	28° 42′ 40″ N

Declination	15° 27′ 48″ N	Departure	68.2
	90° 00′ 00″	Diff. Long.	77′ W
Polar Dist.	74° 32′ 12″		

Altitude	28° 49		
S. D.	+ 15′ 54″		
	29° 04′ 54″		
Dip	— 5′ 22″		
	28° 59′ 32″		
R. & P.	— 1′ 37″		
True Alt.	28° 57′ 55″		
Lat.	28° 42′ 40″	Secant	.05700
Pol. Dist.	74° 32′ 12″	Cosecant	.01602
	2(132° 12′ 47″		
Half Sum	66° 06′ 23″	Cosine	9.60761
True Alt.	28° 57′ 55″		
Remainder	37° 08′ 28″	Sine	9.78080
		Log Haversine	9.46143

A.T.S. 2 —	19 hrs. 39′ 40″	Long. at sight	7° 11′ 45″ W
A.T.G. 2 —	20 hrs. 08′ 27″	Diff. Long.	1° 17′ 00″ W
Long in Time	28′ 47″	Long. at Noon	8° 28′ 45″ W

PROBLEM No. 7.

April 23, 1918. A. M. Obs. Alt. Sun's L. L. 23° 15. Dip 26 ft. Chron. read 0 hrs. 03′ 12″ A. M. which was slow on March 16th 4′ 28″ and gaining 11″.7 daily. Lat. at noon 27° 23 S. Ship run from sight to noon N 28° E 62 miles.

Chron.	12 hrs. 03′ 12″	37.5 days	
slow	+ 4′ 28″	11″.7	
	12 hrs. 07′ 40″	439″ Acc. rate	
Acc. rate	— 7′ 19″		
M.T.G. 22 —	12 hrs. 00′ 21″	Lat. at Noon	27° 23′ 00″ S
Eq. T.	+ 1′ 30″	Diff. Lat.	54′ 42″ S
A.T.G. 22 —	12 hrs. 01′ 51″	Lat. at sight	28° 17′ 42″ S

Declination	12° 11 N	Departure 29.1
	90° 00	Diff. Long. 33′ E
Polar Dist.	102° 11	

Altitude	23° 15′		
S. D.	+ 15′ 54″		
	23° 30′ 54″		
Dip	— 5′		
	23° 25′ 54″		
R. & P.	— 2′ 05″		
True Alt.	23° 23′ 49″		
Lat.	28° 17′ 42″	Secant	.05528
Pol. Dist.	102° 11	Cosecant	.00989
	2(153° 52′ 31″		
Half Sum	76° 56′ 15″	Cosine	9.35427
True Alt.	23° 23′ 49″		
Remainder	53° 32′ 26″	Sine	9.90537
		Log Haversine	9.32481

A.T.S. 22 —	20 hrs. 21′ 06″	Long. at sight	124° 48′ 45″ E
A.T.G 22 —	12 hrs. 01′ 51″	Diff. Long.	33′ E
Long. in Time	8 hrs. 19′ 15″	Long. at Noon	125° 21′ 45″ E

PROBLEM No. 8.

Nov. 28, 1918. A. M. Obs. Alt. Sun's L. L. 50° 25. Dip 30 ft. Chron, read 9 hrs. 33′ 10″ A. M. which was fast on Oct. 22d 3′ 28″ and losing 4″.7 daily. Lat. at noon 0° 10′ 30″ N. Ship run from sight to noon N 79° E 31 miles.

Chron.	21 hrs. 33′ 10″	36.8 days	
fast	— 3′ 28″	4″.7	
	21 hrs. 29′ 42″	173″ Acc. rate	
Acc. rate	+ 2′ 53″		
M.T.G. 27 —	21 hrs. 32′ 35″	Lat. at Noon	0° 10′ 30″ N
Eq. T.	+ 12′ 12″	Diff. Lat.	5′ 54″ S
A.T.G. 27 —	21 hrs. 44′ 47″	Lat. at sight	0° 04′ 36″ N

Declination	21° 12 S	Departure	30.4
	90° 00	Diff. Long.	30′ 24″ E
Polar Dist.	111° 12		

Altitude	50° 25		
S. D.	+ 16′ 12″		
	50° 41′ 12″		
Dip	— 5′ 22″		
	50° 35′ 50″		
R. & P.	— 42″		
True Alt.	50° 35′ 08″		
Lat.	0° 04′ 36″	Secant	.00000
Polar Dist.	111° 12	Cosecant	.03043
	2(161° 51′ 44″		
Half Sum	80° 55′ 52″	Cosine	9.19751
True Alt.	50° 35′ 08″		
Remainder	30° 20′ 44″	Sine	9.70353
		Log Haversine	8.93147

A.T.S. 27 —	21 hrs. 44′ 04″	Long. at sight	0° 10′ 45″ W
A.T.G. 27 —	21 hrs. 44′ 47″	Diff. Long.	30′ 24″ E
Long. in Time	43″	Long. at Noon	0° 19′ 39″ E

PROBLEM No. 9.

March 21, 1918. P. M. Obs. Alt. Sun's L. L. 34° 17′ 30″. Dip 36 ft. Chron. read 9 hrs. 45′ 17″ A. M. which was fast on Feb. 27th 1 hr. 06′ and losing 9″.5 daily. Lat. at noon 23° 15 S. Ship run from noon to sight N 24° W 56 miles.

Chron.	21 hrs. 45′ 17″	21.8 days	
fast	— 1 hr. 06′	9″.5	
	20 hrs. 39′ 17″	207″ Acc. rate	
Acc. rate	+ 3′ 27″		
M.T.G. 20 —	20 hrs. 42′ 44″	Lat. at Noon	23° 15′ 00″ S
Eq. T.	— 7′ 30″	Diff. Lat.	51′ 12″ N
A.T.G. 20 —	20 hrs. 35′ 14″	Lat. at sight	22° 23′ 48″ S
Declination	0° 01′ 30″ S	Departure	22.8
	90° 00′ 00″	Diff. Long.	25′ E
Polar Dist.	89° 58′ 30″		

Altitude	34° 17′ 30″		
S. D.	+ 16′		
	34° 33′ 30″		
Dip	— 5′ 53″		
	34° 27′ 37″		
R. & P.	— 1′ 17″		
True Alt.	34° 26′ 20″		
Lat.	22° 23′ 48″	Secant	.03407
Polar Dist.	89° 58′ 30″	Cosecant	.00000
	2(146° 48′ 38″		
Half Sum	73° 24′ 19″	Cosine	9.45589
True Alt.	34° 26′ 20″		
Remainder	38° 57′ 59″	Sine	9.79856
		Log Haversine	9.28852

A.T.S. 20 —	27 hrs. 29′ 15″	Long. at sight	103° 30′ 15″ E
A.T.G. 20 —	20 hrs. 35′ 14″	Diff. Long.	25′ E
Long. in Time	6 hrs. 54′ 01″	Long. at Noon	103° 55′ 15″ E

PROBLEM No. 10.

Sept. 30, 1918. A. M. Obs. Alt. Sun's L. L. 38° 16′ 45″. Dip, 24 ft. Chron. read 11 hrs. 17′ 25″ P. M. which was fast on Aug. 28th 2 hrs. 15′ and gaining 4″.7 daily. Lat. at noon 41° 16 N. Ship run from sight to noon S 84° W 63 miles.

Chron.	11 hrs. 17′ 25″	33.4 days
fast	— 2 hrs. 15′	4″.7
	9 hrs. 02′ 25″	157″ Acc. rate
Acc. rate	— 2′ 37″	
M.T.G. 30 —	8 hrs. 59′ 48″	Lat. at Noon 41° 16′ 00″ N
Eq. T.	+ 9′ 54″	Diff. Lat. 6′ 36″ N
A.T.G. 30 —	9 hrs. 09′ 42″	Lat .at sight 41° 22′ 36″ N
Declination	2° 43′ 54″ S	Departure 62.7
	90° 00′ 00″	Diff. Lon. 83′ W
Polar Dist.	92° 43′ 54″	

Altitude	38° 16′ 45″		
S. D.	+ 16′		
	38° 32′ 45″		
Dip	— 4′ 48″		
	38° 27′ 57″		
R. & P.	— 1′ 07″		
True Alt.	38° 26′ 50″		
Lat.	41° 22′ 36″	Secant	.12476
Polar Dist.	92° 43′ 54″	Cosecant	.00049
	2(172° 33′ 20″		
Half Sum	86° 16′ 40″	Cosine	8.81173
True Alt.	38° 26′ 50″		
Remainder	47° 49′ 50″	Sine	9.86993
		Log Haversine	8.80691

A.T.S. 29 —	22 hrs. 02′ 40″	Long. at sight	166° 45′ 30″ W
A.T.G. 29 —	33 hrs. 09′ 42″	Diff. Long.	1° 23′ W
Long. in Time	11 hrs. 7′ 02″	Long. at Noon	168° 08′ 30″W

CHAPTER X.

DEVIATION BY AZIMUTH OF SUN.

This problem is to find the error and deviation of the compass.

An azimuth is the true bearing of a heavenly body, and is reckoned from the North point in North latitude, and from the South point in South latitude from 0° to 180°.

For Example: If in North latitude and the sun bore N 80° E, the azimuth would read N 80° E, if it bore S 80° E, the azimuth would be N 100° E.

Put down chronometer time and correct fast or slow as given, using Astronomical time same as in longitude sights. Answer will be Mean Time Greenwich.

The difference between Greenwich time and Ship's time is the longitude in time, so we proceeed as follows:

From Table 7 (Bowditch) take out longitude in time.

Apply longitude in time to M. T. G. as follows:

Longitude East, add

Longitude West, subtract

Answer will be Mean Time Ship, expressed M. T. S.

From Nautical almanac take out Equation of time for Greenwich date and time and Sun's declination to nearest degree.

Apply equation of time to M. T. G. as by sign given in almanac.

Answer will be Apparent time ship, expressed A. T. S. If Apparent time ship is less than 12 hours the time is P. M.

If Apparent time ship is more than 12 hours, subtract 12 hours from it and the time will be A. M.

Take out from Azimuth table sun's true bearing for latitude to nearest degree, and declination to nearest degree, and A. T. Ship A. M. or P. M.

(Note)—Notice whether latitude and declination are same or contrary names.

The azimuth is given in the table for every 10 minutes, and if A. T. S. is in between, it will be necessary to interpolate between the two bearings by following rule:

Subtract less from greater bearing, and reduce total to minutes.

This will give the change in 10 minutes.

Divide change by 10, the result will be change in 1 minute.

Multiply change in 1 minute by number of minutes, time is away from the nearest azimuth.

Apply this change to azimuth and result will be Sun's true bearing.

Place compass bearing and true bearing under each other, and subtract less from greater.

Result will be error of compass.

Name the compass error as follows:

If true bearing is to right of compass bearing the error is east.

If true bearing is to left of compass bearing the error is west.

(Note)—Always imagine that you are standing in the centre of the compass, and looking toward the bearings.

Under the error put down the variation as given in example, and apply as follows:

Variation and error same name, subtract less from greater.

Variation and error different name, add the two.

The result will be deviation of compass on course steered at time of taking the bearing.

Name the deviation as follows:

The deviation will always be named the same as the error, unless you subtract the error from the variation, it will then be named the opposite name to error.

PROBLEM No. 1.

June 10, 1918. A. M. Chron. read. 11 hrs. 16′ 23″ A. M. Lat. 18° S. Long. 62° 10 W. Sun bore by compass S. 110° 21 E. Var. 6° East.

		Decl. 23° N Lat. 18° S.
Chron. or M. T. G. 9		23 hrs. 16′ 23″
Long in time		4 hrs. 08′ 40″
M. T. S.		19 hrs. 07′ 43″
Eq. T.		+55″
A. T. S.		19 hrs. 08′ 38″
	—	12 hrs.
		7 hrs. 08′ 38″ A. M.
Sun's Comp. Brg.		S 110° 21 E
Sun's True Brg.		S 117° 25 E
Error		7° 04 W
Variation		6° 00 E
Deviation		13° 04 W

PROBLEM No. 2.

Dec. 11, 1918. A. M. Chron. read 4 hrs. 23′ 23″ A. M. Lat. 40° N. Lon. 91° 02 E. Sun bore by compass N 135° 16 E. Var. 41° East.

		Lat. 40 N
		Decl. 23° S
M. T. G. 10		16 hrs. 23′ 23″
Long. in time	+	6 hrs. 04′ 08″
M. T. S.		22 hrs. 27′ 31″
Eq. T.		+ 7′ 04″
A. T. S.		22 hrs. 34′ 37″
	—	12 hrs.
		10 hrs. 35 A. M.
Sun's Comp. Brg.		N 135° 16 E
Sun's True Brg.		N 158° 35 E
Eorror		23° 19 E
Variation		41° 00 E
Deviation		17° 41 W

PROBLEM No. 3.

Jany. 3, 1918. A. M. Chron. read. 1 hr. 50′ 12″ P. M. Lat. 28° N. Lon. 91° 15 W. Sun bore by compass N 126° 30 E. Var. 7° East.

Lat. 28° N
Decl. 23° S

M. T. G. 2		25 hrs. 50′ 12″
Long. in time		6 hrs. 05′
M. T. S.		19 hrs. 45′ 12″
Eq. T.		— 4′ 25″
A. T. S.		19 hrs. 40′ 47″
	—	12 hrs.
		7 hrs. 41 A. M.
Sun's Comp. Brg.		N 126° 30 E
Sun's True Brg.		N 122° 27 E
Error		4° 03 W
Variation		7° 00 E
Deviation		11° 03 W

PROBLEM No. 4.

March 12, 1918. A. M. Chron. read. 7 hrs. 15′ 26″ A. M. Lat. 18° S. Lon. 2° 46′ E. Sun bore by compass S 103° 14′ E. Var. 21° East.

Lat. 18° S
Decl. 4° S

M. T. G. 11		19 hrs. 15′ 26″
Long. in time		+ 11′ 04″
M. T. S.		19 hrs. 26′ 30″
Eq. T.		— 10′ 05″
A. T. S.		19 hrs. 16′ 25″
	—	12 hrs.
		7 hrs. 16 A. M.
Sun's Comp. Brg.		S 103° 14 E
Sun's True Brg.		S 92° 04 E
Error		11° 10 E
Variation		21° 00 E
Deviation		9° 50 W

PROBLEM No. 5.

Nov. 14, 1918. P. M. Chron. read. 11 hrs. 16′ 28″ P. M. fast 4′ 16″. Lat. 23° N. Sun bore by compass N 110° 25 W. Var. 7° W. Long. 100° 45 W.

Lat. 23° N
Decl. 18° S

Chron. 14		11 hrs. 16′ 26″
Fast		4′ 16″
M. T. G. 14		11 hrs. 12′ 12″
Long. in time	—	6 hrs. 43′
M. T. S.		4 hrs. 29′ 12″
Eq. T.		+ 15′ 32″
A. T. S.		4 hrs. 45′ 44″ P. M.
Sun's Comp. Brg.		N 110° 25 W
Sun's True Brg.		N 114° 03 W
Error		3° 38 W
Variation		7° 00 W
Deviation		3° 22 E

PROBLEM No. 6.

April 9, 1918. A. M. Chron. read. 1 hr. 02′ 15″ A. M. Lat. 36° N. Lon. 110° 25 E. Sun bore by compass N 103° 15 E. Var. 6° East.

Lat. 36° N
Decl. 7° N

M. T. G. 8		13 hrs. 02′ 15″
Long. in time	+	7 hrs. 21′ 40″
M. T. S.		20 hrs. 23′ 55″
Eq. T.		— 1′ 54″
A. T. S.		20 hrs. 22′ 01″
	—	12 hrs.
		8 hrs. 22 A. M.
Sun's Comp. Brg.		N 103° 15 E
Sun's True Brg.		N 106° 33 E
Error		3° 18 E
Var.		6° 00 E
Deviation		2° 42 W

PROBLEM No. 7.

May 17, 1918. P. M. Chron. read. 8 hrs. 02' 20″ P. M. Lat. 41 ° N. Lon. 65° 18 W. Sun bore by compass N 123° 15 W. Var. 17° 15 E.

Lat. 41° N
Decl. 19° N

M. T. G. 17	8 hrs. 02′ 20″
Long in time	4 hrs. 21′ 12″
M. T. S.	3 hrs. 41′ 08″
Eq. T.	+ 3′ 46″
A. T. S.	3 hrs. 44′ 54″ P M.
Sun's Comp. Brg.	N 123° 15 W
Sun's True Brg.	N 97° 10 W
Error	26° 05 E
Variation	17° 15 E
Deviation	8° 50 E

PROBLEM No. 8.

Sept. 16, 1918. P. M. Chron. read 14 hrs. 18′ 15″. Lat. 10° S. Lon. 179° 15 W. Sun bore by compass S 128° 30 W. Var. 25° West.

Lat. 10° S
Decl. 3° N

M. T. G. 16	14 hrs. 18′ 15″
Long. in time	11 hrs. 57′
M. T. S.	2 hrs. 21′ 15″
Eq. T.	+ 5′ 08″
A. T. S.	2 hrs. 26′ 23″ P. M.
Sun's Comp. Brg.	S 128° 30 W
Sun's True Brg.	S 107° 50 W
Error	20° 40 W
Variation	25° 00 W
Deviation	4° 20 E

PROBLEM No. 9.

Aug. 10, 1918. A. M. Chron. read. 5 hrs. 40 A. M. Lat. 40° S. Long. 60 East. Sun bore by compass S 112° 30 E. Var. 20° E.

Lat. 40° S
Decl. 16° N

M. T. G. 9	17 hrs. 40′ 00″
Long. in time	4 hrs. 00′ 00″
M. T. S.	21 hrs. 40′ 00″
Eq. T.	— 5′ 22″
A. T. S.	21 hrs. 34′ 38″
	— 12 hrs.
	9 hrs. 34′ 38″ A. M.
Sun's Comp. Brg.	S 112° 30 E
Sun's True Brg.	S 141° 17 E
Error	28° 47 W
Variation	20° 00 E
Deviation	48° 47 W

PROBLEM No. 10.

May 19, 1918. P. M. Chron. read. 7 hrs. 09′ 01″ P. M. Lat. 42° N. Lon. 60° 16 W. Sun bore by compass N 75° 20 W. Var. 17° 10 W.

Lat. 42° N
Decl. 20° N

M. T. G. 19	7 hrs. 09′ 01″
Long. in time	4 hrs. 01′ 04″
M. T. S.	3 hrs. 07′ 57″
Eq. T.	+ 3′ 43″
A. T. S.	3 hrs. 11′ 40″ P. M.
Sun's Comp. Brg.	N 75° 20 W
Sun's True Brg.	N 103° 25 W
Error	28° 05 W
Variation	17° 10 W
Deviation	10° 55 W

CHAPTER XI.

DEVIATION BY AMPLITUDE.

An amplitude is the bearing of a heavenly body at rising or setting.

It is reckoned from the East and West points of the compass toward North and South from 0° to 90°.

East and West are reckoned as 0° and North and South as 90°.

To convert a compass bearing into an amplitude proceed as follows:

If the sun bore at rising N 82° E, the compass amplitude would be E 8° N.

If the sun bore at setting S 79° W, the compass amplitude would be W 11° S.

Put down chronometer time and correct fast or slow as given.

Answer will be Mean time Greenwich.

Take out Sun's Declination for Greenwich date and time for degree and nearest minute.

From Table 44 (Bowditch) take out the following Logs:

Secant of Latitude. Rejecting 10 from Index Number.

Sine of Declination.

Add these two logs together.

Look for Sine (Table 44) that agrees with sum of logs, and the degrees and minutes from top and side of page will be True Amplitude.

Name the true amplitude as follows:

If sun is rising name it East. If declination is North, name N. If South, S.

If sun is setting name it West. If declination is North, Name, N. If South, S.

Now convert compass bearing into an amplitude, and apply it to true amplitude as follows:

If both are of same name, subtract less from greater.

If different names, add the two.

Result will be error of compass.

Name the error of compass as follows:

If true bearing is to right of compass bearing, the error is East.

If true bearing is to left of compass bearing, the error is West.

Always imagine yourself standing in the centre of the compass, and looking towards the bearings.

Under the error put down the variation given in example, and apply as follows:

Variation and error same name, subtract less from greater.

Variation and error different name, add the two.

Answer will be Deviation.

Name the deviation as follows:

The deviation will always be named the same as the error, unless you subtract the error from the variation, it will then be named opposite name to error.

PROBLEM No. 1.

Jany. 24, 1918. Sun bore at rising N 83° E. Chron. read 2 hrs. 12 P. M. Lat 46° 15 S. Var 8° East.

M. T. G. 24 — 2hrs. 12′		Declination	19° 19 S
Secant of Lat. =	0.16020	True Amplitude	E 28° 35 S
Sine of Decl. —	9.51955	Comp. Amplitude	E 7° 00 N
Sine	9.67975	Error	35° 35 E
		Var.	8° 00 E
		Deviation	27° 35 E

PROBLEM No. 2.

Nov. 8, 1918. Sun bore at rising S 71° E. Chron. read 1 hr. 50 P. M. Lat. 43° 02 N. Var. 25° West.

M. T. G. 8 — 1 hr. 50′ Declination 16° 27 S

Secant of Lat.	43° 02 =	0.13611
Sine of Decl.	16° 27 =	9.45206
	Sine	9.58817

True Amplitude	E 22° 48 S
Comp. Amplitude	E 19° 00 S
Error	3° 48 E
Var.	25° 00 W
Deviation	28° 48 E

PROBLEM No. 3.

June 6, 1918. Sun bore at setting S. 82° W. Chron. read 9 hrs. 15′ A. M. Lat. 40° 12 N. Var. 6° E.

M. T. G. 5 — 21 hrs. 15′ Declination 22° 35 N

Secant of Lat.	40° 12	= 10.11702
Sine of Decl.	22° 35	= 9.58436
	Sine	9.70138

True Amplitude	W 30° 11 N
Comp. Amplitude	W 8° 00 S
Error	38° 11 E
Var.	6° 00 E
Deviation	32° 11 E

PROBLEM No. 4.

Feby. 10, 1918. Sun bore at rising S 86° E. Chron. read 8 hrs. 15′ A. M. Lat. 0° 10 N. Var. 15° E.

M. T. G. 9 — 20 hrs. 15′ Declination 14° 34 S.

Declination is = to true amplitude in Lat. 0°

True Amplitude	E 14° 34 S
Comp. Amplitude	E 4° 00 S
Error	10° 34 E
Var.	15° 00 E
Deviation	4° 26 W

PROBLEM No. 5.

Sept. 23, 1918. Sun bore at setting N 79° W. Chron. read 2 hrs. 10′ P. M. Lat. 48° N. Var. 2° West.

M. T. G. 23 — 2 hrs. 10′ Declination 0° 07 N.

True amplitude is East or West or 0° in Decl. 0°

True Amplitude	W 00° 00
Comp. Amplitude	W 11° 00 N
Error	11° 00 W
Var.	2° 00 W
Deviation	9° 00 W

PROBLEM No. 6.

Aug. 10, 1918. Sun bore at setting S 81° W. Chron. read 10 hrs. 28′ A. M. slow 32′. Lat 18° 28 S. Var. 30° East.

Chron.	22 hrs. 28′	
Slow	+ 32′	Declination 15° 45 N
M. T. G. 9	23 hrs. 00′	

Secant of Latitude	18° 28 =	0.02296
Sine of Declination	15° 45 =	9.43367
	Sine	9.45663

True Amplitude	W 16° 38 N
Comp. Amplitude	W 9° 00 S
Error	25° 38 E
Var.	30° 00 E
Deviation	4° 22 W

PROBLEM No. 7.

March 7, 1918. Sun bore at rising S 84° E. Chron. read 4 hrs. 16′ P. M. Lat. 36° 18 N. Variation 3° West.

M. T. G. 7 — 4 hrs. 16′ Declination 5° 25 S

Secant of Lat.	36° 18 =	0.09370
Sine of Decl.	5° 25 =	8.97496
	Sine	9.06866

True Amplitude	E 6° 43 S
Comp. Amplitude	E 6° 00 S
Error	0° 43 E
Var.	3° 00 W
Deviation	3° 43 E

PROBLEM No. 8.

June 22, 1918. Sun bore at setting S 84° W. Chron. read 11 hrs. 18′ P. M. slow 40′. Lat 36° 18 N. Var. 10° West.

Chron.	11 hrs. 18′	
Slow	+ 40′	Declination 23° 27 N
M. T. G. 22	11 hrs. 58′	

Secant of Lat.	36° 18 =	0.09370
Sine of Decl.	23° 27 =	9.59983
	Sine	9.69353
True Amplitude		W 29° 35 N
Comp. Amplitude		W 6° 00 S
Error		35° 35 E
Var.		10° 00 W
Deviation		45° 35 E

PROBLEM No. 9.

Dec. 1, 1918. Sun bore at rising S 60° E. Chron read 2 hrs. 46′ A. M. fast 34′. Lat. 0° 18 S. Var. 10° W.

Chron	14 hrs. 46′	Declination 21° 40 S
Fast	— 34′	
M. T. G. 30	14 hrs. 12′	

True Amplitude	E 21° 40 S
Comp. Amplitude	E 30° 00 S
Error	8° 20 W
Var.	10° 00 W
Deviation	1° 40 E

PROBLEM No. 10.

March 22, 1918. Sun bore at setting N 78° W. Chron. read 10 hrs. 36′ P. M. fast 30′. Lat 0° 14 N. Var. 3° E.

Chron.	10 hrs. 36′	
Fast	—— 30′	Declination 0° 35 N
M. T. G. 22	10 hrs. 06′	

True Amplitude	W 0° 35 N
Comp. Amplitude	W 12° 00 N
Error	11° 25 W
Variation	3° 00 E
Deviation	14° 25 W

PROBLEM No. 11.

Jany. 2, 1918. Sun bore at rising N. 89° E. Chron. read 1 hr. 50′ A. M. Lat. 41° 21 N. Var. 35° East.

M. T. G. 1 — 13 hrs. 50′ Declination 23° 00 S

Secant of Lat.	41° 21	= 0.12454
Sine of Decl.	23° 00	= 9.59188
	Sine	9.71642
True Amplitude		E 31° 22 S
Comp. Amplitude		E 1° 00 N
Error		32° 22 E
Var.		35° 00 E
Deviation		2° 38 W

PROBLEM No. 12.

Oct. 16, 1918. Sun bore at setting S 88° W. Chron. read 2 hrs. 10′ P. M. Lat. 18° 24 N. Variation 3° East.

M. T. G. 16 — 2 hrs. 10′ Declination 8° 43 S.

Secant of Lat.	18° 24	= 0.02279
Sine of Decl.	8° 43	= 9.18055
	Sine	9.20334
True Amplitude		W 9° 11 S
Comp. Amplitude		W 2° 00 S
Error		7° 11 W
Var.		3° 00 E
Deviation		10° 11 W

CHAPTER XII.

LATITUDE BY POLARIS.

The latitude by Polaris (or North star) can be obtained at any time the star is visible, as long as the sea horizon is clear enough to obtain a proper altitude.

Find M. T. G. using the astronomical time always.

Apply longitude in time to M. T. G. as follows:

Longitude East, add.

Longitude West, subtract.

Result will be Mean Time Ship.

Take out correction from Table III (Nautical almanac) for Mean Time Ship, and add it to M. T. S.

Take out Sun's Right Ascension from Page 2 (Almanac) for Greenwich date.

Take out correction from Table III (Nautical almanac) for longitude in time, and apply this correction to Sun's Right Ascension as follows:

Longitude West, add.

Longitude East, subtract.

Add together M. T. S. (corrected) and Sun's Right Ascension (corrected). Result will be Local Siderial Time, expressed L. S. T.

If L. S. T. exceeds 24 hours, subtract 24 hours from it.

Correct star's altitude as follows.

Index error as per sign, if any.

Dip (table 14) subtract.

Refraction (table 20A) subtract.

Result will be True Altitude.

Take out correction from Table I (Nautical almanac) for L. S. T. and apply this correction to true altitude by sign given in table.

Result will be approximate latitude.

LATITUDE BY POLARIS.

PROBLEM No. 1.

Jany. 31, 1918. A. M. Obs. Alt. *Polaris 24° 55. Dip 36 ft. Chron. read 0 hrs. 22′ 00″ P. M. Long. 93° 30 W.

M.T.G. 30 —	24 hrs. 22′ 00″	Obs. Alt.	24° 55
Long. in T.	6 hrs. 14′	Dip	— 5′ 53″
M. T. S.	18 hrs. 08′ 00″		24° 49′ 07″
Corr. Table III	+ 2′ 59″	Refr.	— 2′ 05″
Sun's R. A.	20 hrs. 39′ 35″		
Corr. for L. T.	+ 1′ 01″	True Alt.	24° 47′ 02″
		Corr.	+ 1° 03′ 36″
	38 hrs. 51′ 35″		
	— 24 hrs.	Lat.	25° 50′ 38″ N
L. S. T.	14 hrs. 51′ 35″		

PROBLEM No. 2.

Jany. 30, 1918. A. M. Obs. Alt. *Polaris 27° 27. Dip 36 ft. Chron. read 0 hrs. 17′ 00″ P. M. Long. 90° W.

M.T.G. 29 —	24 hrs. 17′ 00″	Obs. Alt.	27° 27
Long.in T.—	6 hrs.	Dip	— 5′ 53″
M. T. S.	18 hrs. 17′ 00″		27° 21′ 07″
Corr.	+ 3′	Refr.	— 1′ 52″
Sun's R. A.	20 hrs. 35′ 39″		
Corr.	+ 59″	True Alt.	27° 19′ 15″
		Corr.	+ 1° 03′ 02″
	38 hrs. 56′ 38″		
	— 24 hrs.	Lat.	28° 22′ 17″ N
L. S. T.	14 hrs. 56′ 38″		

PROBLEM No. 3.

July 15, 1918. P. M. Obs. Alt. *Polaris 26° 17. Dip 20 ft. Chron. read 1 hr. 15′ 21″ P. M. Long. 82° 17 E.

M.T.G. 15 —	1 hr. 15′ 21″	Obs. Alt.	26° 17
Long. in T.	5 hrs. 29′ 08″	Dip	— 4′ 23″
M. T. S.	6 hrs. 44′ 29″		26° 12′ 37″
Corr.	+ 1′ 06″	Refr.	— 1′ 57″
Corr. R. A.	7 hrs. 29′ 12″		
		True Alt.	26° 10′ 40″
L. S. T.	14 hrs. 14′ 47″	Corr.	+ 1° 06′ 27″
Sun's R. A.	7 hrs. 30′ 07″	Lat.	27° 17′ 07″ N
Corr.	— 55″		
Corr. R. A.	7 hrs. 29′ 12″		

PROBLEM No. 4.

Nov. 10, 1918. A. M. Obs. Alt. *Polaris 36° 21. Dip 17 ft. Chron. read 11 hrs. 15′ 20″ A. M. Long. 98° 22 W.

M.T.G. 9 —	23 hrs. 15′ 20″	Obs. Alt.	36° 21
Long. in T.	6 hrs. 33′ 28″	Dip	— 4′ 02″
M. T. S.	16 hrs. 41′ 52″		36° 16′ 58″
Corr.	+ 2′ 45″	Refr.	— 1′ 12″
Sun's R. A.	15 hrs. 11′ 24″		
Corr.	+ 1′ 04″	True Alt.	36° 15′ 46″
		Corr.	+ 8′ 14″
	31 hrs. 57′ 05″		
	— 24 hrs.	Lat.	36° 24′ 00″ N
L. S. T.	7 hrs. 57′ 05″		

PROBLEM No. 5.

Aug. 6, 1918. A. M. Obs. Alt. *Polaris 28° 16. Dip 23 ft. Chron. read 2 hrs. 16′ 28″ A. M., slow 1′ 25″. Long. 98° 21 E.

Chron.	14 hrs. 16′ 28″	Sun's R. A.	8 hrs. 52′ 54″
slow	+ 1′ 25″	Corr.	— 1′ 04″
M.T.G. 5 —	14 hrs. 17′ 53″	Corr. S. R. A.	8 hrs. 51′ 50″
Long.in T.+	6 hrs. 33′ 24″		
		Obs. Alt.	28° 16
M. T. S.	20 hrs. 51′ 17″	Dip	— 4′ 42″
Corr.	+ 3′ 25″		
Sun's R. A.	8 hrs. 51′ 50″		28° 11′ 18″
		Refr.	— 1′ 48″
	29 hrs. 46′ 32″		
	— 24 hrs.	True Alt.	28° 09′ 30″
		Corr.	— 29′ 11″
L. S. T.	5 hrs. 46′ 32″		
		Lat.	27° 40′ 19″ N

PROBLEM No. 6.

June 8, 1918. A. M. Obs. Alt. *Polaris 23° 12′ 15″. Dip 38 ft. Chron. read 11 hrs. 55′ 25″ A. M. Long. 110° 15 W.

M.T.G. 7 —	23 hrs. 55′ 25″	Obs. Alt.	23° 12′ 15″
Long.in T.—	7 hrs. 21′	Dip	— 6′ 02″
M. T. S.	16 hrs. 34′ 25″		23° 06′ 13″
Corr.	+ 2′ 43″	Refr.	— 2′ 16″
Sun's R. A.	5 hrs. 00′ 17″		
Corr.	+ 1′ 12″	True Alt.	23° 03′ 57″
		Corr.	— 35′ 23″
L. S. T.	21 hrs. 38′ 37″		
		Lat.	22° 28′ 34″ N

PROBLEM No. 7.

May 20, 1918. P. M. Obs. Alt. *Polaris 42° 16′ 30″ Dip 39 ft. Chron. read 4 hrs. 16′ 23″ P. M., fast 3′ 18″. Long. 3° 15 E.

Chron.	4 hrs. 16′ 23″	Sun's R. A.	3 hrs. 49′ 19″
fast	— 3′ 18″	Corr.	— 2″
M.T.G. 20 —	4 hrs. 13′ 05″	Corr. R. A.	3 hrs. 49′ 17″
Long. in T.	+ 13′		
		Obs. Alt.	42° 16′ 30″
M. T. S.	4 hrs. 26′ 05″	Dip	— 6′ 07″
Corr.	+ 44″		
Sun's R. A.	3 hrs. 49′ 17″		42° 10′ 23″
		Refr.	— 1′ 04″
L. S. T.	8 hrs. 16′ 06″		
		True Alt.	42° 09′ 19″
		Corr.	+ 13′ 48″
		Lat.	42° 23′ 07″ N

PROBLEM No. 8.

Oct. 6, 1918. A. M. Obs. Alt. *Polaris 50° 24′ 45″. Dip 40 ft. Chron. read 9 hrs. 22′ 03″ A. M., slow 4′ 23″. Long. 18° 16 W.

Chron.	21 hrs. 22′ 03″	Obs. Alt.	50° 24′ 45″
slow	+ 4′ 23″	Dip	— 6′ 12″
M.T.G. 5 —	21 hrs. 26′ 26″		50° 18′ 33″
Long. in T.	1 hr. 13′ 04″	Refr.	— 49″
M. T. S.	20 hrs. 13′ 22″	True Alt.	50° 17′ 44″
Corr.	+ 3′ 19″	Corr.	+ 28′ 48″
Sun's R. A.	12 hrs. 53′ 24″		
Corr.	+ 12″	Lat.	50° 46′ 32″ N
L. S. T.	9 hrs. 10′ 17″		

PROBLEM No. 9.

Feby. 12, 1918. A. M. Obs. Alt. *Polaris 48° 16. Dip 21 ft. Chron. read 2 hrs. 06′ 28″ P. M. Long. 152° West.

M.T.G. 11 —	26 hrs. 06′ 28″
Long.in T. —	10 hrs. 08′ 00″
M. T. S.	15 hrs. 58′ 28″
Corr.	+ 2′ 37″
Sun's R. A.	21 hrs. 26′ 54″
Corr.	+ 1′ 40″
	37 hrs. 29′ 39″
	— 24 hrs.
L. S. T.	13 hrs. 29′ 39″

Obs. Alt.	48° 16′ 00″
Dip	— 4′ 29″
	48° 11′ 31″
Refr.	— 52″
True Alt.	48° 10′ 39″
Corr.	+ 1° 07′ 42″
Lat.	49° 18′ 21″ N

PROBLEM No. 10.

June 6, 1918. P. M. Obs. Alt. *Polaris 29° 41. Dip 20 ft. Chron. read 8 hrs. 16′ 21″ A. M. Long. 161° 15 E.

M.T.G. 5 —	20 hrs. 16′ 21″
Long.in T.+	10 hrs. 45′
	31 hrs. 01′ 21″
	— 24 hrs.
M. T. S.	7 hrs. 01′ 21″
Corr.	+ 1′ 09″
Sun's R. A.	4 hrs. 50′ 38″
L. S. T.	11 hrs. 53′ 08″

Sun's R. A.	4 hrs. 52′ 24″
Corr.	— 1′ 46″
Corr. S. R. A.	4 hrs. 50′ 38″
Alt.	29° 41
Dip	— 4′ 23″
	29° 36′ 37″
Refr.	— 1′ 42″
True Alt.	29° 34′ 55″
Corr.	+ 1° 01′ 39″
Lat.	30° 36′ 34″ N

PROBLEM No. 11.

Oct. 25, 1918. A. M. Obs. Alt. *Polaris 47° 15. Dip 26 ft. Chron. read 1 hr. 16′ 28″ P. M. Long. 100° W.

M.T.G. 24 —	25 hrs. 16′ 28″	Obs. Alt.	47° 15′
Long.in T.—	6 hrs. 40′	Dip	— 5′
M. T. S.	18 hrs. 36′ 28″		47° 10′
Corr.	+ 3′ 03″	Refr.	— 48″
Sun's R. A.	14 hrs. 12′ 15″		
Corr.	+ 1′ 05″	True Alt.	47° 09′ 12″
		Corr.	+ 24′ 14″
	32 hrs. 52′ 51″		
	— 24 hrs.	Lat.	47° 33′ 26″ N
L. S. T.	8 hrs. 52′ 51″		

PROBLEM No. 12.

July 4, 1918. A. M. Obs. Alt. *Polaris 28° 32′ 00″. Dip 27 ft. Chron. read 11 hrs. 58′ 03″ A. M. Long. 94° 50 West.

M.T.G. 3	23 hrs. 58′ 03″	Obs. Alt.	28° 32′ 00″
Long. in T.	6 hrs. 19′ 20″	Dip	— 5′ 06″
M. T. S.	17 hrs. 38′ 43″		28° 26′ 54″
Corr.	+ 2′ 54″	Refr.	— 1′ 47″
Sun's R. A.	6 hrs. 42′ 48″		
Corr.	+ 1′ 02″	True Alt.	28° 25′ 07″
		Corr.	— 1° 04′ 48″
	24 hrs. 25′ 27″		
	— 24 hrs.	Lat.	27° 20′ 19″ N
L. S. T.	0 hrs. 25′ 27″		

PROBLEM No. 13.

Feby. 12, 1918. P. M. Obs. Alt. *Polaris 26° 12′ 00″. Dip 14 ft. Chron. read 7 hrs. 23′ 15″ A. M. Long. 175° East.

M.T.G. 11 —	19 hrs. 23′ 15″	Sun's R. A.	21 hrs. 22′ 57″
Long.in T.	11 hrs. 40′ 00″	Corr.	— 1′ 55″
	31 hrs. 03′ 15″	Corr. S.R.A.	21 hrs. 21′ 02″
	— 24 hrs.		
		Obs. Alt.	26° 12′ 00″
M. T. S.	7 hrs. 03′ 15″	Dip	— 3′ 40″
Corr.	+ 1′ 09″		
Sun's R. A.	21 hrs. 21′ 02″		26° 08′ 20″
		Refr.	— 1′ 58″
	28 hrs. 25′ 26″		
	— 24 hrs.	True Alt.	26° 06′ 22″
		Corr.	— 48′ 48″
L. S. T.	4 hrs. 25′ 26″		
		Lat.	25° 17′ 34″ N

PROBLEM No. 14.

April 10. 1918. A. M. Obs. Alt. *Polaris 13° 16. Dip 18 ft. Chron. read 0 hrs. 02′ 03″ A. M., fast 5′ 12″. Long. 81° 15 East.

Chron. 9 —	12 hrs. 02′ 03″	Sun's R. A.	1 hr. 07′ 41″
fast	— 5′ 12″	Corr.	— 53″
M.T.G. 9 —	11 hrs. 56′ 51″	Corr. S. R. A.	1 hr. 06′ 48″
Long.in T.+	5 hrs. 25′		
		Obs. Alt.	13° 16′
M. T. S.	17 hrs. 21′ 51″	Dip	— 4′ 09″
Corr.	+ 2′ 51″		
Sun's R. A.	1 hr. 06′ 48″		13° 11′ 51″
L. S. T.	18 hrs. 31′ 30″	Refr.	— 3′ 55″
		True Alt.	13° 07′ 56″
		Corr.	+ 18′ 13″
		Lat.	13° 26′ 09″ N

CHAPTER XIII.

LONGITUDE BY SUN, ALTITUDE AZIMUTH, MERIDIAN ALTITUDE OF SUN, AND MERCATOR SAILING COMBINED.

This problem is worked the same as previous methods for obtaining latitude by sun, longitude by sun, and course and distance by Mercators Sailing.

The difference in the chronometer sights are that two rates for the chronometer are given, and it is necessary to find the daily rate.

To find daily rate of chronometer proceed as follows:

If 1st and 2d rate are both fast or slow, subtract less from greater.

If 1st and 2d rate are one fast and one slow, add the two.

Turn this result into seconds, by multiplying minutes by 60, and add to the result the seconds.

Divide number of seconds by number of days between the rates, and the result will be Daily Rate.

Put down the chronometer time and apply to it the last rate given in example.

Find the number of days between last rate and date of example, and multiply number of days by Daily Rate already obtained.

Result will be Accumulated rate, which apply to chronometer, and the result will be M. T. G.

The latitude at noon is found if sun's meridian altitude is given, and latitude at sight found as in previous noon position sights.

Now proceed to find the longitude at sight and noon as in previous noon position sights.

The altitude azimuth is worked in conjunction with a regular longitude by sun sight, and the sun's true bearing is obtained without the use of azimuth tables.

To find the sun's true bearing by altitude azimuth proceed as follows:

Add together true altitude, latitude and polar distance, using the same altitude, latitude and polar distance that longitude sight was worked with.

Divide sum by 2, answer will be Half Sum.

Under half sum put down polar distance, and subtract less from greater, result will be Remainder.

From Table 44 (Bowditch) take out the following Logs: Secant of Altitude. Rejecting 10 from the Index Number.

Secant of Latitude. Rejecting 10 from Index Number.

Cosine of Half Sum.

Cosine of Remainder.

Add these four logs together, and divide sum by 2.

Log Cosine (Table 44) that agrees nearest to sum of logs will be the Half Azimuth, read in degrees and minutes.

Multiply Half Azimuth by 2. Result will be sun's true bearing.

If in North Lat. name the true bearing N. If sight is A. M. East. P. M. West.

If in South Lat. name the true bearing S. If sight is A. M. East. If P. M. West.

Under true bearing put down compass bearing and obtain error and deviation of compass same as in azimuths from the tables.

The position of the ship at noon is then put down as Lat. A and Long. A, and the course and distance found by Mercators Sailing to position given in example.

LONGITUDE BY SUN, LATITUDE BY SUN, ALTITUDE AZIMUTH AND MERCATORS SAILING COMBINED

PROBLEM No. 1.

Jany. 14, 1918. A. M. at ship. Obs. Alt. Sun's L. L. 35° 28′ 18″. Dip 15 ft. Index Error + 50″. Chron. read 2 hrs. 30′ 44″ which was slow on Nov. 25th 10′ 20″ and on Dec. 11th was slow 13′ 49″. Obs. Mer. Alt. of Sun's L. L. at noon was 59° 59 S. Long. by D. R. 87° W. Ship run from sight to noon S 73° W (true) 48 miles.

Sun bore by compass N 108° 15 E. Var. 16° West.

Required Latitude and Longitude at sight and Noon?

Required Error and Deviation of compass by altitude azimuth?

Required True course and distance by Mercators sailing from noon to Lat. 7° 15 S. Long. 125° 35 W.

Obs. Mer. Alt.	59° 59′ 00″ S	Approx. G. T. 14 — 5 hrs. 48′ or 6 hrs.
I. E.	+ 50″	Declination 21° 21′ 18″ S.
	59° 59′ 50″	
S. D.	+ 16′ 12″	True Alt. 60° 11′ 44″ S
		90° 00′ 00″
	60° 16′ 02″	
Dip	— 3′ 48″	Zenith Dist. 29° 48′ 16″ N
		Declination 21° 21′ 18″ S
	60° 12′ 14″	
R. & P.	— 30″	Lat. at Noon 8° 26′ 58″ N
		Diff. Lat. 14′ 00″ N
True Alt.	60° 11′ 44″ S	
		Lat. at sight 8° 40′ 58″ N
Chron.	2 hrs. 30′ 44″	Middle Lat. 9°
slow	+ 13′ 49″	Departure 45.9
		Diff. Long. 46′ 30″ W
	2 hrs. 44′ 33″	
Acc. rate	+ 7′ 23″	Chron. slow Nov. 25th 10′ 20″
		Chron. slow Dec. 11th 13′ 49″
M.T.G. 14	— 2 hrs. 51′ 56″	
Eq. T.	— 9′ 04″	3′ 29″
		losing = 209″
A.T.G. 14	—2 hrs. 42′ 52″	209″
Declination	21° 22′ 36″ S	16 days = 13″ daily rate
	90° 00′ 00″	34.1 days interval
Polar Dist.	111° 22′ 36″	443″ = 7′ 23 Acc. rate losing

Obs. Alt.	35° 28′ 18″		
I. E.	+ 50″		
	35° 29′ 08″		
S. D.	+ 16′ 12″		
	35° 45′ 20″		
Dip	— 3′ 48″		
	35° 41′ 32″		
R. & P.	— 1′ 14″		
True Alt.	35° 40′ 18″		
Lat.	8° 40′ 58″	Secant	.00501
Polar Dist.	111° 22′ 36″	Cosecant	.03097
	2(155° 43′ 52″		
Half Sum	77° 51′ 56″	Cosine	9.32261
True Alt.	35° 40′ 18″		
Remainder	42° 11′ 38″	Sine	9.82719
		Log Haversine	9.18578

A. T. S.	13 — 20 hrs. 55′ 33″	
A. T. G.	13 — 26 hrs. 42′ 52″	
Long. in Time	5 hrs. 47′ 19″	
	4(347′ 199″ 180	
Long at sight	86° 49′ 45″	W
Diff. Long.	46′ 30″	W
Long. at noon	87° 36′ 15″	W

True Alt.	35° 40′ 18″	Secant	.09022
Lat.	8° 40′ 58″	Secant	.00501
Polar Dist.	111° 22′ 36″		
	2(155° 43′ 52″		
Half Sum	77° 51′ 56″	Cosine	9.32261
Polar Dist.	111° 22′ 36″		
Remainder	33° 30′ 40″	Cosine	9.92102
			2(19.33886
		Cosine	9.66943

Half Azimuth		62° 09	
		× 2	
True Bearing	N	124° 18′	E
Comp. Bearing	N	108° 15	E
Error		16° 03	E
Var.		16° 00	W
Dev.		32° 03	E

Lat. A	8° 27 N	Mer. Parts	505.4	Long. A	87° 36 W
Lat. B	7° 15 S	Mer. Parts	433.2	Long. B	125° 35 W
	15° 42	Mer. Parts	938.6		37° 59
	60				60
	900				2220
	42				59
	942′ Diff. Lat.			Diff. Long.	2279

Log of Diff. Long.. 2279 =	13.35774	
Log of Mer. Parts 938.6 =	2.97248	
Tangent	10.38526	= Course S 67° 37 W
Secant of Course 67° 37 =	0.41930	
Log of Diff. Lat. 942 =	2.97405	
Log	3.39335	= Dist. 2474 miles.

Answer.
At sight Lat. 8° 40′ 58″ N. Long. 86° 49′ 45″ W.
At noon Lat. 8° 26′ 58″ N. Long. 87° 36′ 15″ W.
Error of compass 16° 03 East. Deviation 32° 03 East.
True Course S 67° 37 W. Distance 2474 miles.

LONGITUDE BY SUN, ALTITUDE AZIMUTH AND MERCATORS SAILING COMBINED.

Feby. 28, 1918. A. M. Obs. Alt. Sun's L. L. 23° 23. Dip 38 ft. Chron. read 3 hrs. 16′ 28″ A. M., which was fast on Jany. 1st 14′ 28″ and on Jany. 28th was slow 2′ 12″.

Lat. at Noon was 28° 17 S. Ship run from sight to noon N 56° W (true) 49 miles.

Required Latitude and Longitude at sight and noon?

Sun bore by compass S 108° 16 E. Variation 14° West.

Required Error and Deviation of compass by Altitude Azimuth?

Required True course and distance made by Mercators Sailing from noon to Lat. 16° 12 S. Long. 15° 10 E.

Chron.	15 hrs. 16′ 28″
slow	+ 2′ 12″
	15 hrs. 18′ 40″
Acc. rate	+ 18′ 52″
M.T.G. 27 —	15 hrs. 37′ 32″
Eq. T.	— 12′ 51″
A.T.G. 27 —	15 hrs. 24′ 41″
Declination	8° 17′ 18″ S
	90° 00′ 00″
Polar Dist.	81° 42′ 42″

Chron. fast Jan. 1st.	14′ 28″
Chron. slow Jan. 28th	2′ 12″
lost	16′ 40″
	= 1000″

1000″ / 27 days = 37″

37″ daily rate losing
30.6 days interval

1132″ Acc. rate = 18′ 52″

Lat. at Noon	28° 17′ 00″ S
Diff. Lat.	27′ 24″ S
Lat. at sight	28° 44′ 24″ S

Departure 40.6
Diff. Long. 46′ West

Obs. Alt.	23° 23		
S. D.	+ 16′ 06″		
	23° 39′ 06″		
Dip	— 6′ 02″		
	23° 33′ 04″		
R. & P.	— 2′ 04″		
True Alt.	23° 31′ 00″		
Lat.	28° 44′ 24″	Secant	.05707
Pol. Dist.	81° 42′ 42″	Cosecant	.00455
	2(133° 58′ 06″		
Half Sum	66° 59′ 03″	Cosine	9.59218
True Alt.	23° 31′		
Remainder	43° 28′ 03″	Sine	9.83755
		Log Haversine	9.49135

A.T.S. 27 —	19 hrs. 29′ 20″	Long. at sight	61° 09′ 45″ E
A.T.G. 27 —	15 hrs. 24′ 41″	Diff. Long.	46′ W
Long. in T.	4 hrs. 04′ 39″	Long. at Noon	60° 23′ 45″ E

True Alt.	23° 31′ 00″	Secant	.03766
Lat.	28° 44′ 24″	Secant	.05707
Pol. Dist.	81° 42′ 42″		
	2(133° 58′ 06″		
Half Sum	66° 59′ 03″	Cosine	9.59218
Polar Dist.	81° 42′ 42″		
Remainder	14° 43′ 39″	Cosine	9.98548
			2(19.67239
		Cosine	9.83619

Half Azimuth	46° 42
	2
True Bearing	S 93° 24 E
Comp. Bearing	S 108° 16 E
Error	14° 52 E
Var.	14° 00 W
Deviation	28° 52 E

Lat. A 28° 17 S	Mer. Parts 1759.4	Long. A 60° 24 E
Lat. B 16° 12 S	Mer. Parts 978.7	Long. B 15° 10 E
Diff. Lat. 725′	Mer. Parts 780.7	Diff. Long. 2714′

Log of Diff. Long.	2714 =	13.43361
Log of Mer. Parts	780.7 =	2.89248
Tangent		10.54113 = Course N 73° 57W
Secant of Course	73° 57 =	0.55834
Log of Diff. Lat.	725 =	2.86034
Log		3.41868 = Dist. 2622 miles.

Answer:

Latitude at sight 28° 44′ 24″ S. Long. at sight 61° 09′ 45″ E.

Latitude at noon 28° 17′ 00″ S. Long. at noon 60° 23′ 45″ E.

Error of compass 14° 52 East. Deviation 28° 52 East.

True course N 73° 57 W. Distance 2622 miles.

PROBLEM No. 3.

Sept. 3, 1918. A. M. Obs. Alt. Sun's L. L. 18° 18. Dip 32 ft. Chron. read 5 hrs. 16′ 28″ P. M., which was fast on Aug. 5th 4′ 12″ and on Aug. 31st was slow 3′ 12″.

Lat. at Noon 4° 16 N. Ship run from sight to noon S 18° W (true) 48 miles.

Sun bore by compass N 92° E. Variation 28° West.

Required Latitude and Longitude at sight and noon?

Required error and deviation of compass by altitude azimuth?

Required true course and distance by Mercators Sailing from noon to Lat. 5° 28 S. Long. 150° East.

Chron.	5 hrs. 16′ 28″	Chron. fast Aug. 5th	4′ 12″
slow	+ 3′ 12″	Chron. slow Aug. 31st	3′ 12″
	5 hrs. 19′ 40″	lost	7′ 24″
Acc. rate	+ 55″	7′ 24″ = 444″	
M.T.G. 3 —	5 hrs. 20′ 35″	26 days =	17″.1
			Daily Rate
Eq. T.	+ 33″		
		Daily Rate	17″.1
A.T.G. 3 —	5 hrs. 21′ 08″	Interval	3.2 days
Lat. at Noon	4° 16′ 00″ N	Acc. Rate	55″ losing
Diff. Lat.	45′ 42″ N		
		Departure	14.8
Lat. at sight	5° 01′ 42″ N	Diff. Long.	15′ West

Declination	7° 41 N
	90° 00
Polar Dist.	82° 19

Obs. Alt.	18° 18
S. D.	+ 15′ 54″
	18° 33′ 54″
Dip	— 5′ 33″
	18° 28′ 21″
R. & P.	— 2′ 44″
True Alt.	18° 25′ 37″

True Alt.	18° 25′ 37″		
Lat.	5° 01′ 42″	Secant	.00168
Pol. Dist.	82° 19	Cosecant	.00392
	2(105° 46′ 19″		
Half Sum	52° 53′ 09″	Cosine	9.78063
True Alt.	18° 25′ 37″		
Remainder	34° 27′ 32″	Sine	9.75267
		Log Haversine	9.53890

A.T.S. 2 —	19 hrs. 11′ 49″	Long. at sight	152° 19′ 45″ W
A.T.G. 2 —	29 hrs. 21′ 08″	Diff. Long.	15′ W
Long. in T.	10 hrs. 09′ 19″	Long. at Noon	152° 34′ 45″ W

True Alt.	18° 25′ 37″	Secant	.02287
Lat.	5° 01′ 42″	Secant	.00168
Polar Dist.	82° 19		
	2(105° 46′ 19″		
Half Sum	52° 53′ 09″	Cosine	9.78063
Polar Dist.	82° 19′		
Remainder	29° 25′ 51″	Cosine	9.93998
			2(19.74516
		Cosine	9.87258

Half Azimuth	41° 47
	2
True Bearing	N 83° 34 E
Comp. Bearing	N 92° 00 E
Error	8° 26 W
Var.	28° 00 W
Dev.	19° 34 E

Lat. A	4° 16 N	Mer. Parts	254.5	Long. A	152° 35 W
Lat. B	5° 28 S	Mer. Parts	326.3	Long. B	150° 00 E
Diff. Lat.	584′	Mer. Parts	580.8	Diff. Long.	3445′

Log of Diff. Long.	3445 =	13.53719	
Log of Mer. Parts	580.3 =	2.76403	
	Tangent	10.77316	= Course S 80° 26W
Secant of Course 80° 26	=	0.77938	
Log of Diff. Lat.	584 =	2.76641	
	Log	3.54579	= Dist. 3514 miles.

Answer:
Lat. at sight 5° 1′ 42″ N. Long. at sight 152° 19′ 45″ W.
Lat. at noon 4° 16′ 00″ N. Long. at noon 152° 34′ 45″ W.
Error of compass 8° 26 West. Deviation 19° 34 East.
True course S 80° 26 W. Distance 3514 miles.

PROBLEM No. 4.

Dec. 2, 1918. A. M. Obs. Alt. Sun's L. L. 24° 16. Dip 26 ft. Chron. read 6 hrs. 23′ 12″ A. M., which was fast on Nov. 3d 8′ 12″ and on Nov. 28th was fast 6′ 20″. Lat. at noon was 23° 18 N. Ship run from sight to noon N 43° W (true) 52 miles.

Sun bore by compass N 116° 15 E. Variation 19° East.

Required Latitude and Longitude atsight and noon?

Required error and deviation of compass by altitude azimuth?

Required true course and distance from noon to Lat. 0° 23 S Long. 0° 23 W by Mercators sailing?

Chron.	18 hrs. 23′ 12″	Chron. fast Nov. 3rd	8′ 12″
fast	— 6′ 20″	Chron. fast Nov. 28th	6′ 20″
	18 hrs. 16′ 52″	lost	1′ 52″
Acc. rate	+ 17″	1′ 52″ = 112″	
M.T.G. 1 —	18 hrs. 17′ 09″	25 days	= 4″.5
Eq. T.	+ 10′ 49″		Daily rate
		Daily rate	4″.5
A.T.S. 1 —	18 hrs. 27′ 58″	Interval	3.7 days
Declination	21° 50′ 48″ S	Acc. rate	17″ losing
	90° 00′ 00″		
		Lat. at Noon	23° 18′ 00″ N
Polar Dist.	111° 50′ 48″	Diff. Lat.	38′ 00″ S
		Lat. at sight	22° 40′ 00″ N
		Departure	35.5
		Diff. Long.	38′ 30″ West

Obs. Alt.	24° 16′		
S. D.	+ 16′ 12″		
	24° 32′ 12″		
Dip	— 5′		
	24° 27′ 12″		
R. & P.	— 2′		
True Alt.	24° 25′ 12″		
Lat.	22° 40′	Secant	.03491
Pol. Dist.	111° 50′ 48″	Cosecant	.03238
	2(158° 56′ 00″		
Half Sum	79° 28′ 00″	Cosine	9.26199
True Alt.	24° 25′ 12″		
Remainder	55° 02′ 48″	Sine	9.91363
		Log Haversine	9.24291

A.T.S. 1 —	20 hrs. 42′ 12″	Long. at sight	33° 33′ 30″ E
A.T.G. 1 —	18 hrs. 27′ 58″	Diff. Long.	38′ 30″ W
Long. in T.	2 hrs. 14′ 14″	Long. at noon	32° 55′ 00″ E

True Alt.	24° 25′ 12″	Secant	.04069
Lat.	22° 40	Secant	.03491
Polar Dist.	111° 50′ 48″		
	2(158° 56′ 00″		
Half Sum	79° 28′ 00″	Cosine	9.26199
Polar Dist.	111° 50′ 48″		
Remainder	32° 22′ 48″	Cosine	9.92659
			2(19.26418
		Cosine	9.63209

Half Azimuth	64° 37
	2
True Bearing	N 129° 14 E
Comp. Bearing	N 116° 15 E
Error	12° 59 E
Var.	19° 00 E
Dev.	6° 01 W

Lat. A 23° 18 N	Mer. Parts 1429	Long. A 32° 55 E
Lat. B 0° 23 S	Mer. Parts 23	Long. B 0° 23 W
Diff. Lat. 1421′	Mer. Parts 1452	Diff. Long. 1998′

Log of Diff. Long. 1998 = 13.30060
Log of Mer. Parts 1452 = 3.16197

Tangent 10.13863 = Course S 53° 59W

Secant of Course 53° 59 = 0.23061
Log of Diff. Lat. 1421 = 3.15259

Log 3.38320 = Dist. 2417 miles.

Answer:
Lat. at sight 22° 40 N. Long. at sight 33° 33′ 30″ E.
Lat. at noon 23° 18 N. Long. at noon 32° 55′ 00″ E.
Error of compass 12° 59 East. Deviation 6° 01 West.
True course S 53° 59 W. Distance 2417 miles.

PROBLEM No. 5.

Jany. 3, 1918. A. M. Obs. Alt. Sun's L. L. 49° 10. Dip 14 ft. Chron. read 7 hrs. 08′ 50″ A. M. which was slow on Nov. 30th 18′ 2″ and on Dec. 7th was slow 19′ 10″.6. Lat. at Noon 37° 21′ 36″ S.

Ship run from sight to noon S 45° W (true) 32 miles.
Sun bore by compass S 73° 12 E. Variation 4° 40 W.
Required Latitude and Longitude at sight and noon?
Required Error and Deviation by altitude azimuth?
True course and distance by Mercators sailing from noon to Lat. 1° 10 N. Long. 5° 16 W.

Chron. slow Nov. 30th 18′ 02″
Chron. slow Dec. 7th 19′ 10″.6

losing 1′ 08″.6 = 68″.6

68″.6

7 days = 9″.8 daily rate
Interval 26.8 days

Acc. rate 262″ = 4′ 22″ losing

Chron.	19 hrs. 08′ 50″	Declination	22° 53′ 48″ S
slow	+ 19′ 10″		90° 00′ 00″
	19 hrs. 28′ 00″	Polar Dist.	67° 06′ 12″

	19 hrs. 28′ 00″		
Acc. rate	+ 4′ 22″	Lat. at Noon	37° 21′ 36″ S
		Diff. Lat.	22′ 36″ N
M.T.G. 2 —	19 hrs. 32′ 22″		
Eq. T.	— 4′ 18″	Lat. at sight	36° 59′ 00″ S
A.T.G. 2 —	19 hrs. 28′ 04″	Departure	22.6
		Diff. Long.	28′ West

Obs. Alt.	49° 10′ 00″		
S. D.	+ 16′ 18″		
	49° 26′ 18″		
Dip	— 3′ 40″		
	49° 22′ 38″		
R. & P.	— 45″		
True Alt.	49° 21′ 53″		
Lat.	36° 59′	Secant	.09756
Pol. Dist.	67° 06′ 12″	Cosecant	.03565
	2(153° 27′ 05″		
Half Sum	76° 43′ 32″	Cosine	9.36102
True Alt.	49° 21′ 53″		
Remainder	27° 21′ 39″	Sine	9.66246
		Log Haversine	9.15669

A.T.S. 2 —	21 hrs. 01′ 57″	Long. at sight	23° 28′ 15″ E
A.T.G. 2 —	19 hrs. 28′ 04″	Diff. Long.	28′ 00″ W
Long. in T.	1 hr. 33′ 53″	Long. at noon	23° 00′ 15″ E

True Alt.	49° 21′ 53″	Secant	.18628
Lat.	36° 59′	Secant	.09756
Polar Dist.	67° 06′ 12″		
	2(153° 27′ 05″		
Half Sum	76° 43′ 32″	Cosine	9.36102
Pol. Dist.	67° 06′ 12″		
Remainder	9° 37′ 20″	Cosine	9.99385
			2(19.63871
		Cosine	9.81935

Half Azimuth	48° 43
	2
True Bearing	S 97° 26 E
Com. Bearing	S 73° 12 E
Error	24° 14 W
Var.	4° 40 W
Deviation	19° 34 W

Lat. A 37° 22 S	Mer. Parts 2406	Long. A 23° 00 E
Lat. B 1° 10 N	Mer. Parts 69	Long. B 5° 16 W
Diff. Lat. 2312′	Mer. Parts 2475	Diff. Long. 1696′

Log of Diff. Long. 1696 = 13.22943
Log of Mer. Parts 2475 = 3.39358

Tangent 9.83585 = Course N 34° 25W

Secant of Course 34° 25 = 0.08357
Log of Diff. Lat. 2312 = 3.36399

Log 3.44756 = Dist. 2803 miles.

Answer:
Lat. at sight 36° 59 S. Long. at sight 23° 28′ 15″ E.
Lat. at noon 37° 21′ 36″ S. Long. at noon 23° 00′ 15″ E.
Error of compass 24° 14 West. Deviation 19° 34 W.
True course N 34° 25 W. Distance 2803 miles.

LONGITUDE BY SUN, LATITUDE BY SUN, ALTITUDE AZIMUTH AND MERCATORS SAILING.

PROBLEM No. 6.

Nov. 15, 1918. A. M. Obs. Alt. Sun's L. L. 50° 25′ Dip 30 ft. Chron. read 9 hrs. 33′ 10″ A. M. which was fast on Oct. 22d 3′ 28″ and losing 4″.7 daily. The Obs. Mer. Alt. Sun's L. L. at noon was 68° 13 S. Long. by D. R. 0°. Ship sailed from sight to noon N 79° E (true) 31 miles.

Sun bore by compass N 82° 16 E. Variation 25° East. Required Latitude and Longitude at sight and noon?

Required error and deviation of compass by altitude azimuth?

Required true course and distance by Mercators sailing from noon to Lat. 24° 18 N Long. 56° 28 W.

Mer. Alt.	68° 13′ 00″ S	Nov. 15 Approx. G. T. 0 hrs.
S. D.	+ 16′ 12″	Declination 18° 21′ 30″ S.
	68° 29′ 12″	
Dip	— 5′ 22″	
	68° 23′ 50″	
R. & P.	— 21″	
True Alt.	68° 23′ 29″	
	90° 00′ 00″	
Zenith Dist.	21° 36′ 31″ N	
Declination	18° 21′ 30″ S	
Lat. at noon	3° 15′ 01″ N	
Diff. Lat.	5′ 54″ S	
		Departure 30.4
Lat. at sight	3° 09′ 07″ N	Diff. Long. 30′ 24″ E.

Chron.	21 hrs. 33′ 10″		
fast	— 3′ 28″	Interval	23.9 days
			4″.7 daily rate
	21 hrs. 29′ 42″		
Acc. rate	+ 1′ 52″	Acc. rate 112″ = 1′ 52″	
M.T.G. 14 —	21 hrs. 31′ 34″	Declination	18° 20′ S
Eq. T.	+ 15′ 26″		90° 00
A.T.G. 14 —	21 hrs. 47′ 00″	Polar Dist.	108° 20

Obs. Alt.	50° 25
S. D.	16′ 12″
	50° 41′ 12″
Dip	— 5′ 22″
	50° 35′ 50″
R. & P.	— 41″
True Alt.	50° 35′ 09″

True Alt.	50° 35′ 09″		
Lat.	3° 09′ 07″	Secant	.00066
Pol. Dist.	108° 20′	Cosecant	.02262
	2(162° 04′ 16″		
Half Sum	81° 02′ 08″	Cosine	9.19273
True Alt.	50° 35′ 09″		
Remainder	30° 26′ 59″	Sine	9.70482
		.Log Haversine	8.92083

A.T.S. 14 —	21 hrs. 45′ 46″	Long. at sight	0° 18′ 30″ W
A.T.G. 14 —	21 hrs. 47′ 00″	Diff. Long.	30′ 24″ E
Long. in T.	1′ 14″	Long. at noon	0° 11′ 54″ E

True Alt.	50° 35′ 09″	Secant	.19726
Lat.	3° 09′ 07″	Secant	.00066
Pol. Dist.	108° 20′		
	2(162° 04′ 16″		
Half Sum	81° 02′ 08″	Cosine	9.19273
Pol. Dist.	108° 20′		
Remainder	27° 17′ 52″	Cosine	9.94871
			2(19.33936
		Cosine	9.66968

Half Azimuth	62° 08
	2
True Bearing	N 124° 16 E
Comp. Bearing	N 82° 16 E
Error	42° 00 E
Var.	25° 00 E
Dev.	17° 00 E

Lat. A 3° 15 N	Mer. Parts 193.8	Long. A	0° 12 E
Lat. B 24° 18 N	Mer. Parts 1494.2	Long. B	56° 28 W
Diff. Lat. 1263′	Mer. Parts 1300.4	Diff. Long.	3400′

Log of Diff. Long.	3400 =	13.53148	
Log of Mer. Parts	1300 =	3.11394	
Tangent		10.41754	= Course N 69° 05W
Secant of Course	69° 05 =	0.44732	
Log of Diff. Lat.	1263 =	3.10140	
Log		3.54872	= Dist. 3538 miles.

Answer:
Lat. at sight 3° 09′ 07″ N. Long. at sight 0° 18′ 30″ W.
Lat. at noon 3° 15′ 01″ N. Long. at noon 0° 11′ 54″ E.
Error of compass 42° East. Deviation 17° East.
True course N 69° 05 W. Distance 3538 miles.

CHAPTER XIV.

LATITUDE BY MERIDIAN ALTITUDE OF PLANET.

This problem is worked the same as latitude by fixed star, with the exception that parallax must be applied to altitude, and the declination corrected for Greenwich date and time.

After finding Mean Time Greenwich, take out declination of planet from almanac for Greenwich date, and the difference in small figures between it and next date.

(Note) Notice whether declination is decreasing or increasing.

Enter Table IV (Nautical Almanac) with the difference at top of page to the nearest number, and the M. T. G. on right hand side to the nearest hour and minute, and read the number obtained from the column.

Apply this number to Planet's Declination for Greenwich date as follows:

If declination is increasing, add the correction.

If declination is decreasing, subtract the correction.

Result will be true declination.

Note: If M. T. G. is over 12 hours, first find the num ber from Table IV that 12 hours will give, and then the balance of hours and minutes left, and add the two.

For Example: Jany. 24th M. T. G. 14 hrs. 14′. Required true declination of Planet "Venus."

Planet's Decl. Jany. 24th	7° 32.3	decreasing
Corr. from Table IV	5.9	
True Declination	7° 26′.4	or 7° 26′ 24″ S

Difference betwen Decl. 24th and 25th = 97.

Taking 97 in 100 column in Table IV, we find for 12 hours number	50
for 2 hrs. 14′, the balance, we find	9
Adding the two	= 59 Corr. for Decl.

The Obs. Mer. Alt. is corrected as follows:

Index Error as per sign if any.

Dip (Table 14) subtract.

Parallax (Table 17) add.

Refraction (Table 20A) subtract.

Result will be true altitude.

Subtract true altitude from 90°, find zenith distance, and apply declination as in previous examples for latitude observations.

Result will be latitude.

LATITUDE BY PLANET.

PROBLEM No. 1.

Oct. 5, 1918. Obs. Mer. Alt. Planet "Saturn" 36° 15′ 20″ S. Dip 18 ft. Chron. read 3 hrs. 08′ 04″ P. M. Required Latitude?

M. T. G. 5 — 3 hrs. 08′ 04″.

Star's Declination	5 —	14° 19.1 decreasing
Corr. Table IV		— 3
True Declination		14° 18.8 or
		14° 18′ 48″ N

Change between Decl. 5th and 6th = 19.

Hor. Parallax 0′.01 from Almanac.

Obs. Mer. Alt.	36° 15′ 20″
Dip	— 4′ 09″
	36° 11′ 11″
Par.	+ 0″
	36° 11′ 11″
Refr.	— 1′ 19″
True Alt.	36° 09′ 52″
	90° 00′ 00″
Zenith Dist.	53° 50′ 08″ N
Declination	14° 18′ 48″ N
Latitude	68° 08′ 56″ N

PROBLEM No. 2.

Dec. 25, 1918. Obs. Mer. Alt. Planet "Jupiter" 41° 12′ 00″ N. Dip 28 ft. Chron. read 6 hrs. 38′ A. M. Required Latitude?

M. T. G. 24 — 18 hrs. 38′.

Planet's Decl. 24th	22° 55.5 increasing
Corr. Table IV	+ 8
True Declination	22° 56.3 or 22° 56′ 18″ N

Change between Decl. 24th and 25th = 8.

Hor. Parallax from Almanac 0′.04.

Obs. Mer. Alt.	41° 12′
Dip	— 5′ 11″
	41° 06′ 49″
Par.	+ 1″
	41° 06′ 50″
Refr.	— 1′ 07″
True Alt.	41° 05′ 43″ N
	90° 00′ 00″
Zenith Dist.	48° 54′ 17″ S
Declination	22° 56′ 18″ N
Latitude	25° 57′ 59″ S

PROBLEM No. 3.

Jany. 2, 1918. Obs. Mer. Alt. Planet "Venus" 69° 07′ 00″ N . Dip 14 ft. Chron. read 1 hr. 12′ P. M.

M. T. G. 2 — 1 hr. 12′.

Planet's Decl. 2d	— 13° 43.1 decreasing
Corr. Table IV	— 1 0
True Declination	13° 42.1 or 13° 42′ 06″ S

Change between Decl. 2d and 3d = 206.

Hor. Parallax from Almanac 0′.34 or 20″.

Obs. Mer. Alt.	69° 07′ 00″ N
Dip	— 3′ 40″
	69° 03′ 20″
Par.	+ 7″
	69° 03′ 27″
Refr.	— 22″
True Alt.	69° 03′ 05″ N
	90° 00′ 00″
Zenith Dist.	20° 56′ 55″ S
Declination	13° 42′ 06″ S
Latitude	34° 39′ 01″ S

PROBLEM No. 4.

April 14, 1918. Obs. Mer. Alt. Planet "Jupiter" 68° 58′ 00″ S. Dip 14 ft. Chron. read 1 hr. 40′ P. M.

M. T. G. 14 — 1 hr. 40′.

Planet's Decl.	14 —	21° 33.8 increasing
Corr. Table IV		+ 1
True Declination		21° 33.9 or 21° 33′ 54″ N

Change between Decl. 14th and 15th = 19.
Hor. Parallax from Almanac 0′.03 or 2″.

Obs. Mer. Alt.	68° 58′ 00″ S
Dip	— 3′ 40″
	68° 54′ 20″
Par.	+ 1″
	68° 54′ 21″
Refr.	— 22″
True Alt.	68° 53′ 59″ S
	90° 00′ 00″
Zenith Dist.	21° 06′ 01″ N
Declination	21° 33′ 54″ N
Latitude	42° 39′ 55″ N

CHAPTER XV.

LATITUDE BY EX-MERIDIAN ALTITUDE OF SUN.

This problem is to find the latitude of the place, when the sun is not visible at noon.

It is possible at certain seasons of the year to obtain the latitude 28 minutes before or after noon.

When sun's declination is opposite name to latitude of observer the interval is greater, when the latitude and declination are the same name the interval is less.

It is very useful in navigation, for if the sun is overcast at noon the latitude by observation would be lost for that day, if this example was not used.

Find the Apparent time ship as follows:

Correct chronometer, and obtain M. T. G.

Under M. T. G. put down Long. in time, and obtain M. T. S., using the same rule for applying Long. in time to M. T. G. as in Azimuths.

Take out Equation of time for Greenwich date and time, and apply it to M. T. S. Result will be Apparent time ship.

It is now necessary to find the time from Noon, so pro ceed as follows:

If A. T. S. is less than 24 hours, subtract it from 24 hours and the result will be the number of minutes and seconds before noon.

If over 24 hours, subtract 24 hours from it. Or if it reads 0 hrs. and so many minutes and seconds, it will be time past noon.

Take out Sun's Declination from almanac for Greenwich date and time.

Square the number of minutes from noon. Using the nearest minute will be close enough for practical purposes.

(Note) To square a number, multiply it by itself. For example: The square of 12′ is 12 multiplied by 12 = 144.

Enter Table 26 (Bowditch) with latitude and declination to nearest degree, and read the number obtained from this table in its proper column. Declination will be found from top of page, latitude from side.

(Note) Notice whether latitude and declination are same or contrary names.

Multiply the square of minutes from noon by this number, and the result will be seconds of altitude correction.

Reduce the seconds to minutes and seconds, and always add it to Sun's Observed Altitude.

(Note) Table 27 (Bowditch) is another method of finding the altitude correction. It is based on the same principle as the foregoing rule—that is, the square of the number of minutes from noon multiplied by correction from Table 26, is given in this table.

After adding to observed altitude the correction, correct altitude for Index Error, Semi-Diameter, Dip, Refraction and Parallax, and obtain true altitude.

Find the Zenith distance, and apply declination to same, as was done in meridian altitude sights.

Result will be latitude at sight.

To find the latitude at noon, it will be necessary to allow the difference of latitude made by the ship from the sight to noon, on the course and distance steered in the interval.

PROBLEM No. 1.

Feby. 9, 1918. Ex. Mer. Alt. Sun's L. L. 42° 16′ 28″ S. Dip 18 ft. Chron. read 6 hrs. 45′ 15″ P. M. Long. 94° 16 W. Lat. by D. R. 33° N.

M. T. G. 9 —	6 hrs. 45′ 15″		Decl. 14° 44′ 42″ S.
Long. in T. —	6 hrs. 17′ 04″	14	
		14	
M. T. S.	0 hrs. 28′ 11″		
Eq. T.	— 14′ 22″	196	
		2″.1 from Table 26	
A. T. S.	0 hrs. 13′ 49″		
Time past noon 14′.		411″ = 6′ 51″ Alt. Corr +	

Obs. Alt.	42° 16′ 28″ S		
Alt. Corr.	+ 6′ 51″	True Alt.	42° 34′ 25″ S
			90° 00′ 00″
	42° 23′ 19″		
S. D.	+ 16′ 12″	Zenith Dist.	47° 25′ 35″ N
		Declination	14° 44′ 42″ S
	42° 39′ 31″		
Dip	— 4′ 09″	Lat. at sight	32° 40′ 53″ N
	42° 35′ 22″		
R. & P.	— 57″		
True Alt.	42° 34′ 25″ S		

PROBLEM No. 2.

June 20, 1918. Ex. Mer. Alt. Sun's L. L. 41° 28′ 13″ N. Dip 20 ft. Chron. read 4 hrs. 45′ 08″ A. M. Long. 105° 15′ E. Lat. by D. R. 25° S.

M.T.G. 19 —	16 hrs. 45′ 08″	Declination 23° 26′ 06″ N.
Long. in T. +	7 hrs. 01′	
		15
M. T. S.	23 hrs. 46′ 08″	15
Eq. T.	— 1′ 07″	
		225
A. T. S.	23 hrs. 45′ 01″	2″.2 from Table 26
	24 hrs.	
		495″ = 8′ 15″ Alt. Corr. +
Time before noon	14′ 59″	

Obs. Alt.	41° 28′ 13″ N		
Alt. Corr.	+ 8′ 15″	True Alt.	41° 46′ 55″ N
			90° 00′ 00″
	41° 36′ 28″		
S. D.	+ 15′ 48″	Zenith Dist.	48° 13′ 05″ S
		Declination	23° 26′ 06″ N
	41° 52′ 16″		
Dip	— 4′ 23″	Lat. at sight	24° 46′ 59″ S
	41° 47′ 53″		
R. & P.	— 58″		
True Alt.	41° 46′ 55″ N		

PROBLEM No. 3.

March 16, 1918. Ex. Mer. Alt. Sun's L. L. 45° 38′ 25″ N. Dip 22 ft. Chron. read March 15th 11 hrs. 59′ 54″ slow 25′ 28″. Long. 168° 20 E. Lat. by D. R. 46° S.

Chron.	11 hrs. 59′ 54″	Declination 2° 08′ 54″ S.
slow	+ 25′ 58″	
		30
M.T.G. 16 —	12 hrs. 25′ 52″	30
Long. in T.	11 hrs. 13′ 20″	
		900
M. T. S.	23 hrs. 39′ 12″	2″ Corr. Table 26
Eq. T.	— 9′ 04″	
		1800″ = 30′ Corr. for Alt.+
A. T. S.	23 hrs. 30′ 08″	
	24 hrs.	
Time before noon	29′ 52″	

Obs. Alt.	45° 38′ 25″	True Alt.	46° 18′ 59″ N
Corr.	+30′		90° 00′ 00″
	46° 08′ 25″	Zenith Dist.	43° 41′ 01″ S
S. D.	+16′	Declination	2° 08′ 54″ S
	46° 24′ 25″	Latitude	45° 49′ 55″ S
Dip	— 4′ 36″		
	46° 19′ 49″		
R. & P.	— 50″		
True Alt.	46° 18′ 59″ N		

PROBLEM No. 4.

June 3, 1918. Ex. Mer. Alt. Sun's L. L. 44° 02 N. Dip 18 ft. Chron. read 10 hrs. 17′ 10″ A. M. slow 3 hrs. 52′ 17″. Long. 35° 15 W. Lat. by D. R. 23° 54 S.

Chron.	22 hrs. 17′ 10″	Declination 22° 15′ 36 N.
slow	3 hrs. 52′ 17″	
		9
M.T.G. 2 —	26 hrs. 09′ 27″	9
Long. in T. —	2 hrs. 21′	
		81
M. T. S.	23 hrs. 48′ 27″	2.5″ corr. from Table 26
Eq. T.	+ 2′ 10″	
		186″ = 3′ 06″ Corr. for Alt. +
A. T. S.	23 hrs. 50′ 37″	
	24 hrs.	
Time before noon	9′ 23″	

Obs. Alt.	44° 02′ 00″ N	True Alt.	44° 15′ 52″ N
Corr.	+ 3′ 06″		90° 00′ 00″
	44° 05′ 06″	Zenith Dist.	45° 44′ 08″ S
S. D.	+ 15′ 48″	Declination	22° 15′ 36″ N
	44° 20′ 54″	Lat. at sight	23° 28′ 32″ S
Dip	— 4′ 09″		
	44° 16′ 45″		
R. & P.	— 53″		
True Alt.	44° 15′ 52″ N		

PROBLEM No. 5.

Oct. 7, 1918. Ex. Mer. Alt. Sun's L. L. 37° 02′ 15″ S. Dip 18 ft. Chron. read 7 hrs. 07′ 41″ A. M. slow 16′ 19″. Long. 70° E. Lat. by D. R. 47° 13 N.

Chron.	19 hrs. 07′ 41″	Declination 5° 13′ 00″ S.
slow	+ 16′ 19″	
		16
M.T.G. 6 —	19 hrs. 24′ 00″	16
Long. in T.	4 hrs. 40′	
		256
M.T.S. 6 —	24 hrs. 04′ 00″	1″.7 from Table 26
Eq. T.	+ 11′ 53″	
		435″ = 7′ 15″ Corr. for Alt. +
A. T. S.	24 hrs. 15′ 53″	
	— 24 hrs.	
Time past noon	15′ 53″	

Obs. Alt.	37° 02′ 15″ S	True Alt.	37° 20′ 12″ S
Corr.	+ 7′ 15″		90° 00′ 00″
	37° 09′ 30″	Zenith Dist.	52° 39′ 48″ N
S. D.	+ 16′	Declination	5° 13′ 00″ S
	37° 25′ 30″	Lat. at sight	47° 26′ 48″ N
Dip	— 4′ 09″		
	37° 21′ 21″		
R. & P.	— 1′ 09″		
True Alt.	37° 20′ 12″ S		

PROBLEM No. 6.

Sept. 24, 1918. Ex. Mer. Alt. Sun's L. L. 50° 19 S. Dip 16 ft. Chron. read 0 hrs. 34′ 10″ P. M., fast 19′ 20. Long. 6° W. Lat. by D. R. 38° 50 N.

Chron.	0 hrs. 34′ 10″	Declination 0° 14′ 48″ S.
fast	— 19′ 20″	
		1
M.T.G. 24 —	0 hrs. 14′ 50″	1
Long. in T.	24′	
		1
M. T. S.	23 hrs. 50′ 50″	2″.4 Corr. from Table 26
Eq. T.	+ 7′ 45″	
		2″.4 Corr. for Alt. +
A. T. S.	23 hrs. 58′ 35″	
	24 hrs.	
Time before noon	1′ 25″	

Obs. Alt.	50° 19′ 00″ S
Corr.	+ 2″
	50° 19′ 02″
S. D.	+ 16′
	50° 35′ 02″
Dip	— 3′ 55″
	50° 31′ 07″
R. & P.	— 42″
True Alt.	50° 30′ 25″ S

True Alt.	50° 30′ 25″ S
	90° 00′ 00″
Zenith Dist.	39° 29′ 35″ N
Declination	0° 14′ 48″ S
Lat. at sight	39° 14′ 47″ N

PROBLEM No. 7.

Dec. 25. 1918. Ex. Mer. Alt. Sun's L. L. 64° 45′ N. Dip 15 ft. Chron. read 3 hrs. 17′ 10″ A. M., slow 13′ 05″. Long. 130° E. Lat. by D. R. 48° 23 S.

Chron.	15 hrs. 17′ 10″
slow	+ 13′ 05″
M.T.G. 24 —	15 hrs. 30′ 15″
Long. in T.	8 hrs. 40′
M. T. S.	24 hrs. 10′ 15″
Eq. T.	+ 18″
A. T. S.	24 hrs. 10′ 33″
	24 hrs.
Time past noon	10′ 33″

Declination 23° 25′ 30″ S.

11
11
———
121
2″.9 Corr. from Table 26
———
351″. = 5′ 51″ Corr. for Alt. +

Obs. Alt.	64° 45′ 00″ N
Corr.	+ 5′ 51″
	64° 50′ 51″
S. D.	+ 16′ 18″
	65° 07′ 09″
Dip	— 3′ 48″
	65° 03′ 21″
R. & P.	— 23″
True Alt.	65° 02′ 58″ N

True Alt.	65° 02′ 58″ N
	90° 00′ 00″
Zenith Dist.	24° 57′ 02″ S
Declination	23° 25′ 30″ S
Lat. at sight	48° 22′ 32″ S

PROBLEM No. 8.

May 29, 1918. Ex. Mer. Alt. Sun's L. L. 64° 25 S. Dip 10 ft. Chron. read 11 hrs. 17′ 56″ A. M., slow 3 hrs. 53′. Long. 49° 30 W. Lat. by D. R. 47° N.

Chron.	23 hrs. 17′ 56″	Declination 21° 33′ 24″ N.
slow	3 hrs. 53′	
		4
M.T.G. 28 —	27 hrs. 10′ 56″	4
Long. in T.	3 hrs. 18′	
		16
M. T. S.	23 hrs. 52′ 56″	2.9 from Table 26
Eq. T.	+ 2′ 53″	
		46″ Corr. for Alt. +
A. T. S.	23 hrs. 55′ 49″	
	24 hrs.	
Time before noon	4′ 11″	

Obs. Alt.	64° 25′ 00″ S	True Alt.	64° 38′ 04″ S
Corr.	+ 46″		90° 00′ 00″
	64° 25′ 46″	Zenith Dist.	25° 21′ 56″ N
S. D.	+ 15′ 48″	Declination	21° 33′ 24″ N
	64° 41′ 34″	Lat. at sight	46° 55′ 20″ N
Dip	— 3′ 06″		
	64° 38′ 28″		
R. & P.	— 24″		
True Alt.	64° 38′ 04″ S		

PROBLEM No. 9.

Jany. 24, 1918. Ex. Mer. Alt. Sun's L. L. 22° 46′ S. Index Error — 1′ 25″. Dip 26 ft. Chron. read 10 hrs. 5′ 2″ P. M. which was slow 7′ 15″. Long. 155° West. Lat. by D. R. 48° N.

Chron.	10 hrs. 05′ 02″	Declination 19° 13′ 54 S.
slow	+ 7′ 15″	
		20
M.T.G. 23 =	34 hrs. 12′ 17″	20
Long. in T.	10 hrs. 20′	
		400
M. T. S.	23 hrs. 52′ 17″	1.4 from Table 26
Eq. T.	— 12′ 13″	
		560″ = 9′ 20″ Corr. for
A. T. S.	23 hrs. 40′ 04″	Alt. +
	24 hrs.	
Time before noon	19′ 56″	

Obs. Alt.	22° 46′	True Alt.	23° 02′ 59″ S
Corr.	+ 9′ 20″		90° 00′ 00″
	22° 55′ 20″	Zenith Dist.	66° 57′ 01″ N
I. E.	— 1′ 25″	Declination	19° 13′ 54″ S
	22° 53′ 55″	Lat. at sight	47° 43′ 07″ N
S. D.	+ 16′ 12″		
	23° 10′ 07″		
Dip	— 5′		
	23° 05′ 07″		
R. & P.	— 2′ 08″		
True Alt.	23° 02′ 59″ S		

PROBLEM No. 10.

July 12, 1918. Ex. Mer. Alt. Sun's L. L. 78° 16′ 28″ S. Dip 26 ft. Chron. read 5 hrs. 0′ 28″ P. M. Long. 75° 18 W. Lat. by D. R. 34° N.

M.T.G. 12 —	5 hrs. 00′ 28″	Declination 22° 01′ 42″ N.
	+ 24 hrs.	
		6
M.T.G. 11 —	29 hrs. 00′ 28″	6
Long. in T.	5 hrs. 01′ 12″	
		36
M. T. S.	23 hrs. 59′ 16″	7.3 from Table 26
Eq. T.	— 5′ 22″	
		263″ = 4′ 23″ Corr. for
A. T. S.	23 hrs. 53′ 54″	Alt. +
	24 hrs.	
Time before noon	6′ 06″	

Obs. Alt.	78° 16′ 28″ S	True Alt.	78° 31′ 26″ S
Corr.	+ 4′ 23″		90° 00′ 00″
	78° 20′ 51″	Zenith Dist.	11° 28′ 34″ N
S. Dia.	+ 15′ 45″	Declination	22° 01′ 42″ N
	78° 36′ 36″	Lat. at sight	33° 30′ 16″ N
Dip	— 5′		
	78° 31′ 36″		
R. & P.	— 10″		
True Alt.	78° 31′ 26″ S		

PROBLEM No. 11.

Sept. 18, 1918. Ex. Mer. Alt. Sun's L. L. 78° 16′ 28″ S. Dip 26 ft. Chron. read 7 hrs. 03′ 00″ A. M. Long. 75° 30 E. Lat. by D. R. 13° N.

M.T.G. 17 —	19 hrs. 03′ 00″	Declination 2° 10′ 00″ N.
Long. in T.	5 hrs. 02′	
		11
M. T. S.	24 hrs. 05′ 00″	11
Eq. T.	+ 5′ 34″	
		121
A. T. S.	24 hrs. 10′ 34″	10″ Corr. from Table 26
	24 hrs.	
		1210″ = 20′ 10″ Corr. for
Time past noon	10′ 34″	Alt. +

Obs. Alt.	78° 16′ 28″ S	True Alt.	78° 47′ 29″ S
Corr.	+ 20′ 10″		90° 00′ 00″
	78° 36′ 38″	Zenith Dist.	11° 12′ 31″ N
S. D.	+16′	Declination	2° 10′ 00″ N
	78° 52′ 38″	Lat. at sight	13° 22′ 31″ N
Dip	— 5′		
	78° 47′ 38″		
R. & P.	— 9″		
True Alt.	78° 47′ 29″ S		

PROBLEM No. 12.

Feby. 7, 1918. Ex. Mer. Alt. Sun's L. L. 42° 00′ 28″ S. Dip 18 ft. Chron. read 6 hrs. 45′ 15″ P. M. Long. 94° W. Lat. by D. R. 32° 50 N.

M. T. G. 7 —	6 hrs. 45′ 15″	Declination 15° 22′ 36″ S.
Long. in T.	6 hrs. 16′	
		15
M. T. S.	0 hrs. 29′ 15″	15
Eq. T.	— 14′ 17″	
		225
Time past noon	14′ 58″	2.1 from Table 26
		472″ = 7′ 52″ Corr. for Alt. +

Obs. Alt.	42° 00′ 28″	True Alt.	42° 19′ 26″ S
Corr.	+ 7′ 52″		90° 00′ 00″
	42° 08′ 20″	Zenith Dist.	47° 40′ 34″ N
S. D.	+ 16′ 12″	Declination	15° 22′ 36″ S
	42° 24′ 32″	Lat. at sight	32° 17′ 58″ N
Dip	— 4′ 09″		
	42° 20′ 23″		
R. & P.	— 57″		
True Alt.	42° 19′ 26″ S		

PROBLEM No. 13.

June 23, 1918. Ex. Mer. Alt. Sun's L. L. 41° 20′ 31″ N. Dip 20 ft. Chron. read 4 hrs. 40′ 18″ A. M. Long. 104° 50 E Lat. by D. R. 25° S.

M.T.G. 22 —	16 hrs. 40′ 18″	Declination 23° 26′ 48″ N.	
Long. in T.	6 hrs. 59′ 20″		
		22	
M. T. S.	23 hrs. 39′ 38″	22	
Eq. T.	— 1′ 46″		
		484	
A. T. S.	23 hrs. 37′ 52″	2.2	from Table 26
	24 hrs.		
		1065″ =	17′ 45″ Corr. for Alt. +
Time before noon	22′ 08″		

Obs. Alt.	41° 20′ 31″ N	True Alt.	41° 48′ 37″ N
Corr.	+ 17′ 45″		90° 00′ 00″
	41° 38′ 16″	Zenith Dist.	48° 11′ 23″ S
S. D.	+ 15′ 42″	Declination	23° 26′ 48″ N
	41° 53′ 58″	Lat. at sight	24° 44′ 35″ S
Dip	— 4′ 23″		
	41° 49′ 35″		
R. & P.	— 58″		
True Alt.	41° 48′ 37″ N		

PROBLEM No. 14.

March 14, 1918. Ex. Mer. Alt. Sun's L. L. 45° 30′ 52″ N. Index Error — 1′ 50″. Dip 21 ft. Chron. read 0 hrs. 50′ 45″ A. M., slow 25′ 50″ . Long. 167° 50 E. Lat. by D. R. 47° S.

Chron.	12 hrs. 50′ 45″	Declination 2° 55′ 12″ S.
slow	+ 25′ 50″	
		18
M.T.G. 13 —	13 hrs. 16′ 35″	18
Long. in T.	11 hrs. 11′ 20″	
		324
M. T. S.	24 hrs. 27′ 55″	1.9 from Table 26
Eq. T.	— 9′ 37″	
		615″ = 10′ 15″ Corr. for Alt. +
A. T. S.	24 hrs. 18′ 18″	
	24 hrs.	
Time past noon	18′ 18″	

Obs. Alt.	45° 30′ 52″ N	True Alt.	45° 50′ 03″ N
Corr.	+ 10′ 15″		90° 00′ 00″
	45° 41′ 07″	Zenith Dist.	44° 09′ 57″ S
S. D.	+ 16′ 06″	Declination	2° 55′ 12″ S
	45° 57′ 13″	Lat. at sight	47° 05′ 09″ S
Dip	— 4′ 29″		
	45° 52′ 44″		
Index Error	— 1′ 50″		
	45° 50′ 54″		
R. & P.	— 51″		
True Alt.	45° 50′ 03″ N		

CHAPTER XVI.

LONGITUDE BY FIXED STAR AND PLANET.

This problem is to determine the longitude of a place by a fixed star and planet, and is accurate as long as the horizon is clear enough to obtain the proper altitude.

A star in the East and another in West taken as close as possible to each other, and projected on the chart by Sumner lines, will make an excellent "fix" for the ship.

For fixed stars:

Correct chronometer same as was done in longitude by sun observations, and obtain Mean Time Greenwich.

From Page 2 (Nautical Almanac) take out Sun's Right Ascension for Greenwich date, and place it under M. T. G.

From Table III (Nautical Almanac) take out correction for hours and minutes of M. T. G., and place it under Sun's Right Ascension.

Add these three together, and the result will be Greenwich Siderial Time, expressed G. S. T.

Take out Star's Declination from Page 95 (Nautical Almanac) for month of example, and Star's Right Ascension from opposite page for month.

Find Polar Distance as follows:

Latitude and Declination, same name, subtract Declination from 90°.

Latitude and Declination different name, add 90° to Declination.

Correct star's observed altitude as follows:

Index Error as per sign if any.

Dip (table 14) subtract.

Refraction (table 20A) subtract.

Result will be true altitude.

Add together true altitude, latitude and polar distance, and divide sum by 2. Result will be Half Sum.

Subtract true altitude from Half Sum. Result will be Remainder.

From Table 44 (Bowditch) take out the following Logs: Secant of Latitude. Rejecting 10 from Index Number.

Cosecant of Polar Distance. Rejecting 10 from Index Number.

Cosine of Half Sum.

Sine of Remainder.

Note: If Polar distance exceeds 90°. Take secant of declination instead.

Add these four logs together, and subtract 10 from Index Number.

Log Haversine (table 45) that agrees with sum of logs will be Star's Hour Angle. Always to be read from top of page or in P. M.

Under Star's Right Ascension put down Star's Hour Angle, and apply as follows:

If star bore West when observation was taken, add the two.

If star bore East when observation was taken, subtract star's hour angle from star's right ascension. Result will be Siderial Time Ship, expressed S. T. S.

Note: If star bore East, and hour angle is greater than right ascension, add 24 hours to right ascension before making subtraction.

Under Siderial time at ship, put down Greenwich Siderial time, and subtract less from greater. Result will be longitude in time.

Turn longitude in time into degrees, minutes and seconds as in previous methods. Result will be longitude.

If Greenwich time is best the longitude is West.

If Greenwich time is least the longitude is East.

PROBLEM No. 1.

Jany. 31, 1918. A. M. Obs. Alt. *Spica 45° 50 bearing West. Dip 36 ft. Chron. read 1 hr. 14′ 35″ P. M. which was fast on Jany. 11th 31′ 34″ and gaining 9″ daily. Lat. 25° 53 North. Long. by D. R. 94° W.

Chron.	1 hr. 14′ 35″	Interval	20 days
fast	— 31′ 34″	Daily rate	9″
	0 hrs. 43′ 01″	Acc. rate	180″ = 3′
Acc. rate	— 3′		
		Declination	10° 44′ 06″ S
M.T.G. 31 —	0 hrs. 40′ 01″		90° 00′ 00″
Sun's R. A.	20 hrs. 39′ 35″		
Corr. Table III	+ 7″	Pol. Dist.	100° 44′ 06″
G. S. T.	21 hrs. 19′ 43″		

Obs. Alt.	45° 50′		
Dip	— 5′ 53″		
	45° 44′ 07″		
Refr.	— 57″		
True Alt.	45° 43′ 10″		
Lat.	25° 53′	Secant	.04591
Polar Dist.	100° 44′ 06″	Cosecant	.00767
	2(172° 20′ 16″		
Half Sum	86° 10′ 08″	Cosine	8.82513
True Alt.	45° 43′ 10″		
Remainder	40° 26′ 58″	Sine	9.81210
		Log Haversine	8.69081

Star's Right Asc.	13 hrs. 20′ 53″
Star's Hour Angle	1 hr. 42′ 23″ +
S. T. S.	15 hrs. 03′ 16″
G. S. T.	21 hrs. 19′ 43″
Long. in time	6 hrs. 16′ 27″

Long. 94° 06′ 45″ West.

PROBLEM No. 2.

Jany. 30, 1918. A. M. Obs. Alt. *Vega 43° 57 bearing East. Dip 36 ft. Chron. read 0 hrs. 56′ 00″ P. M., fast 34′ 25″. Lat. 28° 27 N. Long. by D. R. 90° 30 W.

Chron.	0 hrs. 56′ 00″	Declination	38° 42′ 12″ N
fast	— 34′ 25″		90° 00′ 00″
M.T.G. 30 —	0 hrs. 21′ 35″	Polar Dist.	51° 17′ 48″
Sun's R. A.	20 hrs. 35′ 39″		
Corr.	+ 3″		
G. S. T.	20 hrs. 57′ 17″		

Obs. Alt.	43° 57′		
Dip	— 5′ 53″		
	43° 51′ 07″		
Refr.	— 1′		
True Alt.	43° 50′ 07″		
Lat.	28° 27′	Secant	.05596
Pol. Dist.	51° 17′ 48″	Cosecant	.10767
	2(123° 34′ 55″		
Half Sum	61° 47′ 27″	Cosine	9.67468
True Alt.	43° 50′ 07″		
Remainder	17° 57′ 20″	Sine	9.48881
		Log Haversine	9.32706

Star's R. A.	18 hrs. 34′ 09″
Star's H. A.	3 hrs. 39′ 31″ E or —
S T. S.	14 hrs. 54′ 38″
G. S. T.	20 hrs. 57′ 17″
Long. in Time	6 hrs. 02′ 39″

Long. 90° 39′ 45″ West.

PROBLEM No. 3.

June 12, 1918. P. M. Obs. Alt. *Regulus 26° 18′ 32″ bearing West. Dip 17 ft. Chron. read 2 hrs, 02′ 12″ P. M., fast 14′ 8″. Lat. 37° 18 N. Long. by D. R. 110° E.

Chron.	2 hrs. 2′ 12″	Declination	12° 21′ 54″ N
fast	— 14′ 08″		90° 00′ 00″
M.T.G. 12 —	1 hr. 48′ 04″	Polar Dist.	77° 38′ 06″
Sun's R. A.	5 hrs. 20′ 00″		
Corr.	+ 18″		
G. S. T.	7 hrs. 08′ 22″		

Obs. Alt.	26° 18′ 32″		
Dip	— 4′ 02″		
	26° 14′ 30″		
Refr.	— 1′ 58″		
True Alt.	26° 12′ 32″		
Lat.	37° 18′	Secant	.09937
Pol. Dist.	77° 38′ 06″	Cosecant	.01020
	2(141° 08′ 38″		
Half Sum	70° 34′ 19″	Cosine	9.52207
True Alt.	26° 12′ 32″		
Remainder	44° 21′ 47″	Sine	9.84463
		Log Haversine	9.47627

Star's R. A.	10 hrs. 04′ 02″
Star's H. A.	4 hrs. 25′ 24″ W or +
S. T. S.	14 hrs. 29′ 26″
G. S. T.	7 hrs. 08′ 22″
Long. in T.	7 hrs. 21′ 04″

Long. 110° 16 E.

PROBLEM No. 4.

March 11, 1918. A. M. Obs. Alt. *Antares 28° 16′ 15″ bearing West. Dip 21 ft. Chron. read 8 hrs. 16′ 23″ P. M., slow 32′ 18″. Lat. 22° 18 S. Long. by D. R. 166° 10 W.

Chron.	8 hrs. 16′ 23″	Declination	26° 15′ 06″ S
slow	+ 32′ 18″		90° 00′ 00″
M.T.G. 11 —	8 hrs. 48′ 41″	Polar Dist.	63° 44′ 54″
Sun's R. A.	23 hrs. 13′ 21″		
Corr.	+ 1′ 27″		
G. S. T.	32 hrs. 03′ 29″		

Obs. Alt.	28° 16′ 15″		
Dip	— 4′ 29″		
	28° 11′ 46″		
Refr.	— 1′ 48″		
True Alt.	28° 09′ 58″		
Lat.	22° 18	Secant	.03376
Pol. Dist.	63° 44′ 54″	Cosecant	.04727
	2(114° 12′ 52″		
Half Sum	57° 06′ 26″	Cosine	9.73491
True Alt.	28° 09′ 58″		
Remainder	28° 56′ 28″	Sine	9.68466
		Log Haversine	9.50063

Star's R. A.	16 hrs. 24′ 25″	
Star's H. A.	4 hrs. 33′ 58″	W or +
S. T. S.	20 hrs. 58′ 23″	
G. S. T.	32 hrs. 03′ 29″	
Long. in Time	11 hrs. 05′ 06″	

Long. 166° 16′ 30″ W.

PROBLEM No. 5.

Dec. 16, 1918. P. M. Obs. Alt. *Capella 31° 17′ 12″ bearing East. Dip 19 ft. Chron. read 10 hrs. 12′ 16″ P. M., slow 8′ 03″. Lat. 6° 48 N. Long. by D. R. 33° 15 W.

Chron.	10 hrs. 12′ 16″	Declination	45° 55′ N
slow	+ 8′ 03″		90° 00
M.T.G. 16 —	10 hrs. 20′ 19″	Polar Dist.	44° 05
Sun's R. A.	17 hrs. 37′ 16″		
Corr.	+ 1′ 42″		
G. S. T.	27 hrs. 59′ 17″		

Obs. Alt.	31° 17′ 12″		
Dip	— 4′ 16″		
	31° 12′ 56″		
Refr.	— 1′ 36″		
True Alt.	31° 11′ 20″		
Lat.	6° 48	Secant	.00307
Pol. Dist.	44° 05	Cosecant	.15758
	2(82° 04′ 20″		
Half Sum	41° 02′ 10″	Cosine	9.87756
True Alt.	31° 11′ 20″		
Remainder	9° 50′ 50″	Sine	9.23317
		Log Haversine	9.27138

Star's R. A.	5 hrs. 10′ 45″
Star's H. A.	3 hrs. 24′ 52″ E or —
S. T. S.	1 hr. 45′ 53″
G. S. T.	3 hrs. 59′ 17″
Long. in Time	2 hrs. 13′ 24″

Long. 33° 21 West.

PROBLEM No. 6.

April 16, 1918. P. M. Obs. Alt. *Aldebaran 23° 13′ 20″ bearing West. Dip 26 ft. Chron. read 7 hrs. 01′ 35″ P. M., fast 2′ 27″. Index Error — 2′ 00″. Lat. 11° 47 South. Long. by D. R. 0° 05 E.

Chron.	7 hrs. 01′ 35″	Declination	16° 20′ 42″ N
fast	— 2′ 27″		90° 00′ 00″
M.T.G. 16 —	6 hrs. 59′ 08″	Polar Dist.	106° 20′ 42″
Sun's R. A.	1 hr. 35′ 17″		
Corr.	+ 1′ 09″		
G. S. T.	8 hrs. 35′ 34″		

Obs. Alt.	23° 13′ 20″		
I. E.	— 2′		
	23° 11′ 20″		
Dip	— 5′		
	23° 06′ 20″		
Refr.	— 2′ 16″		
True Alt.	23° 04′ 04″		
Lat.	11° 47	Secant	.00925
Pol. Dist.	106° 20′ 42″	Cosecant	.01793
	2(141° 11′ 46″		
Half Sum	70° 35′ 53″	Cosine	9.52135
True Alt.	23° 04′ 04″		
Remainder	47° 31′ 49″	Sine	9.86786
		Log Haversine	9.41639

Star's R. A.	4 hrs. 31′ 14″	
Star's H. A.	4 hrs. 05′ 42″	W or +
S. T. S.	8 hrs. 36′ 56″	
G. S. T.	8 hrs. 35′ 34″	
Long. in Time	1′ 22″	

Long. 0° 20′ 30″ East.

PROBLEM No. 7.

Dec. 1, 1918. P. M. Obs. Alt. *Capella 31° 17′ 12″ bearing East. Dip 19 ft. Chron. read 9 hrs. 18′ 16″ P. M., slow 8′ 03. Lat. 6° 48 N. Long. by D. R. 5° W.

Chron.	9 hrs. 18′ 16″	Declination	45° 55 N
slow	+ 8′ 03″		90° 00
M.T.G. 1 —	9 hrs. 26′ 19″	Polar. Dist.	44° 05
Sun's R. A.	16 hrs. 38′ 08″		
Corr.	+ 1′ 33″		
G. S. T.	26 hrs. 06′ 00″		

Obs. Alt.	31° 17′ 12″		
Dip	— 4′ 16″		
	31° 12′ 56″		
Refr.	— 1′ 36″		
True Alt.	31° 11′ 20″		
Lat.	6° 48	Secant	.00307
Polar Dist.	44° 05	Cosecant	.15758
	2(82° 04′ 20″		
Half Sum	41° 02′ 10″	Cosine	9.87756
True Alt.	31° 11′ 20″		
Remainder	9° 50′ 50″	Sine	9.23317
		Log Haversine	9.27138

Star's R. A.	5 hrs. 10′ 45″
Star's H. A.	3 hrs. 24′ 52″ E or —
S. T. S.	1 hr. 45′ 53″
G. S. T.	2 hrs. 06′
Long. in T.	20′ 07″

Long. 5° 01′ 45″ West.

PROBLEM No. 8.

Feby. 15, 1918. A. M. Obs. Alt. *Spica 48° 10 bearing West. Dip 36 ft. Chron. read 1 hr. 14′ 35″ P. M. which was fast on Jany. 11th 31′ 34″ and gaining 9″ daily. Lat. 25° 53 North. Long. by D. R. 112° 45 W.

Chron.	1 hr. 14′ 35″	Interval	35 days
fast	— 31′ 34″	Daily rate	9″
	0 hr. 43′ 01″	Acc. rate	315″=5′ 15″
Acc. rate	— 5′ 15″		
		Declination	10° 44′ 12″ S
M.T.G. 15 —	0 hr. 37′ 46″		90° 00′ 00″
Sun's R. A.	21 hrs. 38′ 43″		
Corr.	+ 6″	Polar Dist.	100° 44′ 12″
G. S. T.	22 hrs. 16′ 35″		

Obs. Alt.	48° 10′		
Dip	— 5′ 53″		
	48° 04′ 07″		
Refr.	— 52″		
True Alt.	48° 03′ 15″		
Lat.	25° 53	Secant	.04591
Pol. Dist.	100° 44′ 12″	Cosecant	.00767
	2(174° 40′ 27″		
Half Sum	87° 20′ 13″	Cosine	8.66769
True Alt.	48° 03′ 15″		
Remainder	39° 16′ 58″	Sine	9.80151
		Log Haversine	8.52278

Star's R. A.	13 hrs. 20′ 54″
Star's H. A.	1 hr. 24′ 09″ Wor +
S. T. S.	14 hrs. 45′ 03″
G. S. T.	22 hrs. 16′ 35″
Long. in T.	7 hrs. 31′ 32″

Long. 112° 53 West.

PROBLEM No. 9.

March 20, 1918. P. M. Obs. Alt. *Betelgeux 32° 17′ 30″ bearing East. Dip 26 ft. Chron. read 13 hrs. 16′ 23″, fast 3′ 46″. Lat. 32° 17 N. Long. by D. R. 164° 30 W.

Chron.	13 hrs. 16′, 23″	Declination	7° 23′ 30″ N
fast	— 3′ 46″		90° 00′ 00″
M.T.G. 20 —	13 hrs. 12′ 37″	Polar Dist.	82° 36′ 30″
Sun's R. A.	23 hrs. 48′ 50″		
Corr.	+ 2′ 10″		
G. S. T.	37 hrs. 03′ 37″		

Obs. Alt.	32° 17′ 30″		
Dip	— 5′		
	32° 12′ 30″		
Refr.	— 1′ 32″		
True Alt.	32° 10′ 58″		
Lat.	32° 17	Secant	.07293
Pol. Dist.	82° 36′ 30″	Cosecant	.00363
	2(147° 04′ 28″		
Half Sum	73° 32′ 14″	Cosine	9.45249
True Alt.	32° 10′ 58″		
Remainder	41° 21′ 16″	Sine	9.81998
		Log Haversine	9.34903

Star's R. A.	5 hrs. 50′ 46″
Star's H. A.	3 hrs. 45′ 38″ E or —
S. T. S.	2 hrs. 05′ 08″
G. S. T.	13 hrs. 03′ 37″
Long. in T.	10 hrs. 58′ 29″

Long. 164° 37′ 15″ West.

PROBLEM No. 10.

Feby. 16, 1918. P. M. Obs. Alt. *Rigel 24° 18′ bearing West. Index Error + 2′ 12″. Dip 24 ft. Chron. read 11 hrs. 16′ 28″ P. M. which was fast on Jany. 10th 14′ 12″ and gaining 2″.8 daily. Lat. 16° 46 North. Long. by D. R. 7° 45 E.

Chron.	11 hrs. 16′ 28″	Interval	37.5 days
fast	— 14′ 12″	Daily rate	2.8
	11 hrs. 02′ 16″	Acc. rate	105″=1′ 45″
Acc. rate	— 1′ 45″		
		Declination	8° 17′ 48″ S
M.T.G. 16 —	11 hrs. 00′ 31″		90° 00′ 00″
Sun's R. A.	21 hrs. 42′ 40″		
Corr.	+ 1′ 48″	Polar Dist.	98° 17′ 48″
G. S. T.	32 hrs. 44′ 59″		

Obs. Alt.	24° 18′		
I. E.	+ 2′ 12″		
	24° 20′ 12″		
Dip	— 4′ 48″		
	24° 15′ 24″		
Refr.	— 2′ 09″		
True Alt.	24° 13′ 15″		
Lat.	16° 46′	Secant	.01887
Pol. Dist.	98° 17′ 48″	Cosecant	.00457
	2(139° 17′ 03″		
Half Sum	69° 38′ 31″	Cosine	9.54144
True Alt.	24° 13′ 15″		
Remainder	45° 25′ 16″	Sine	9.85262
		Log Haversine	9.41750

Star's R. A.	5 hrs. 10′ 38″	
Star's H. A.	4 hrs. 06′ 03″	W or +
S. T. S.	9hrs. 16′ 41″	
G. S. T.	8 hrs. 44′ 59″	
Long. in time	31′ 42″	

Long. 7° 55′ 30″ East.

LONGITUDE BY PLANET.

This problem is worked in the same manner as longitude by fixed star, with the exception that the planet's declination and right ascension must be corrected for the Greenwich date and time.

After finding M. T. G. take out planet's declination and right ascension for Greenwich date, and correct it from Table IV (Almanac) same as was done in Lat. by Planet.

Correct the altitude for Index Error, Dip, Parallax and Refraction.

After making these corrections the balance of the problem will be worked in the same manner as longitude by fixed star.

PROBLEM No. 1.

Jany. 31, 1918. A. M. Obs. Alt. Planet "Mars" 18° 55′ bearing West. Dip 36 ft. Chron. read 1 hr. 11′ 13″ P. M., fast 34′ 34″. Lat. 25° 53 N. Required Longitude?

Chron.	1 hr. 11′ 13″	
fast	— 34′ 34″	
M. T. G.	31 — 0 hrs. 36′ 39″	
Sun's R. A.	20 hrs. 39′ 35″	
Corr.	+ 6″	
G. S. T.	21 hrs. 16′ 20″	
Star's Decl.	31— 1° 56.1	Difference 5
Corr. Table IV	0	
True Decl.	1° 56.1 or	1° 56′ 06″ N
		90° 00′ 00″
Polar Dist.		88° 04′ 54″

Obs. Alt.	18° 55
Dip	— 5′ 53″
	18° 49′ 07″
Parallax	+ 9″
	18° 49′ 16″
Refr.	— 2′ 49″
True Alt.	18° 46′ 27″

True Alt.	18° 46′ 27″		
Lat.	25° 53′	Secant	.04591
Pol. Dist.	88° 04′ 54″	Cosecant	.00024
	2(132° 44′ 21″		
Half Sum	66° 22′ 10″	Cosine	9.60302
True Alt.	18° 46′ 27″		
Remainder	47° 35′ 43″	Sine	9.86832
		Log Haversine	9.51749

Star's R. A.	12 hrs. 16′ 24″	Diff. 10
Corr. Table IV	0	
Star's R. A.	12 hrs. 16′ 24″	
Star's H. A.	4 hrs. 40′ 07″	W or +
S. T. S.	16 hrs. 56′ 31″	
G. S. T.	21 hrs. 16′ 20″	
Long. in T.	4 hrs. 19′ 49″	

Long. 64° 57′ 15″ West.

PROBLEM No. 2.

July 6, 1918. A. M. Obs. Alt. Planet "Saturn" 30° 16′ 28″ bearing East. Dip 16 ft. Chron. read 4 hrs. 16′ 28″ P. M., fast 3′ 28″. Lat. 27° 18 N.

Chron.		4 hrs. 16′ 28″
fast		— 3′ 28″
M. T. G.	6 —	4 hrs. 13′ 00″
Sun's R. A.		6 hrs. 54′ 38″
Corr.		+ 42″
G. S. T.		11 hrs. 08′ 20″

Star's Decl.	6 — 17° 37.9	Diff. 20 Decl. de-	
Corr. Table IV	— 4	creasing.	
True Decl.	17° 37.5	or 17° 37′ 30″ N	
		90° 00′ 00″	
Polar Distance		72° 22′ 30″	

Obs. Alt.	30° 16′ 28″		
Dip	— 3′ 55″		
	30° 12′ 33″		
Par.	+ 0		
	30° 12′ 33″		
Refr.	— 1′ 40″		
True Alt.	30° 10′ 53″		
Lat.	27° 18	Secant	.05129
Pol. Dist.	72° 22′ 30″	Cosecant	.02086
	2(129° 51′ 23″		
Half Sum	64° 55′ 41″	Cosine	9.62703
True Alt.	30° 10′ 53″		
Remainder	34° 44′ 48″	Sine	9.75587
		Log Haversine	9.45505

Star's R. A.	6 — 9 hrs. 05′ 19	Incr.
Corr. Table IV	+ 5	Diff. 28
Corr. * R. A.	9 hrs. 05′ 24″	
Star's H. A.	4 hrs. 18′ 12″	E. or —
S. T. S.	4 hrs. 47′ 12″	
G. S. T.	11 hrs. 08′ 20″	
Long. in T .	6 hrs. 21′ 08″	

Long. 95° 17 West.

CHAPTER XVII.

LATITUDE BY MERIDIAN ALTITUDE OF MOON.

This problem is useful to find the latitude when the moon is on the meridian in daylight, but at night cannot be depended upon on account of the sea horizon not being clear enough for proper altitude.

The time of the Moon's Meridian Passage for Greenwich is given on Pages 76-77 (Nautical Almanac) and the difference between transit in small figures. By entering Table IV (almanac) with difference of transit at top of page, and longitude in time at right hand side, will give the correction to be applied to Greenwich transit, to find the time of Moon's Meridian passage at ship.

In West longitude it is to be applied forward.

In East longitude it is to be applied backward.

Correct the chronometer and find the Greenwich date and time.

The Moon's declination changes very fast, and the Nautical Almanac gives the declination for every 2 hours of the day, and the difference in small figures between the even hours.

Take out declination for Greenwich date and closest hour, and the difference in small figures.

Enter Table IV (almanac) with difference at top of page, and number of minutes past the hour in the left hand column, and read the correction for declination in its proper column.

Apply this correction to declination as follows:

Declination decreasing, subtract.

Declination increasing, add.

Result will be true declination.

Take out the Moon's S. D. (Semi-Diameter) and H. P. (Horizontal Parallax) from almanac opposite the hour used.

Put down the observed meridian altitude and apply the S. D. Add for Lower, and subtract for Upper Limb.

Subtract the Dip (table 14).

Enter Table 24 (Bowditch) with H. P. at top of page, and apparent altitude at side, and read correction in proper column.

This correction will be the Parallax and Refraction, always to be added to Altitude.

This will give the true altitude.

Subtract true altitude from 90°, find zenith distance, and apply declination as in previous examples for latitude.

Result will be latitude.

LATITUDE BY MOON.

PROBLEM No. 1.

Feby. 12, 1918. Obs. Mer. Alt. Moon's L. L. 28° 14′ 00″ S. Dip 28 ft. Chron. read 4 hrs. 16′ 28″ P. M.

M. T. G. 12 — 4 hrs. 16′ 28″.

Decl. 12th	4 hrs. =	3° 04.5	Decr. Diff. 305
Corr. Table IV	—	4 1	
True Decl.		3° 00.4	or 3° 00′ 24″ S

S. D. 16.7 H. P. 61.1
Corr. from Table 24 = 51′ 53″.

Mer. Alt.	28° 14′ 00″ S	True Alt.	29° 17′ 24″ S
S. D.	+ 16′ 42″		90° 00′ 00″
	28° 30′ 42″	Zenith Dist.	60° 42′ 36″ N
Dip	— 5′ 11″	True Decl.	3° 00′ 24″ S
	28° 25′ 31″	Latitude	57° 42′ 12″ N
Par. & Ref.	+ 51′ 53″		
True Alt.	29° 17′ 24″ S		

PROBLEM No. 2.

March 18. 1918. Obs. Mer. Alt. Moon's L. L. 68° 21′ 00″ N. Dip 26 ft. Chron. read 6 hrs. 18′ 28″ A. M.

M. T. G. 17 — 18 hrs. 18′ 28″.

Decl. 17th	18 hrs. =	23° 27.3 N	Incr. Diff. 36
Corr. Table IV		+ 6	
True Decl.		23° 27.9 or 23° 27′ 54″ N	

S. D. 15.8. H. P. 57.9.
Corr. from Table 24 = 20′ 52″.

Mer. Alt.	68° 21′ 00″ N	True Alt.	68° 52′ 40″ N
S. D.	+ 15′ 48″		90° 00′ 00″
	68° 36′ 48″	Zenith Dist.	21° 07′ 20″ S
Dip	— 5′	True Decl.	23° 27′ 54″ N
	68° 31′ 48″	Latitude	2° 20′ 34″ N
Par. & Refr.	+ 20′ 52″		
True Alt.	68° 52′ 40″ N		

PROBLEM No. 3.

July 4, 1918. Obs. Mer. Alt. Moon's L. L. 24° 18′ 30″ S. Dip 26 ft. Chron. read 3 hrs. 12′ 18″ P. M., slow 4′ 18″.

Chron.	3 hrs. 12′ 18″
slow	+ 4′ 18″
M. T. G.	4 — 3 hrs. 16′ 36″

Decl 4th	2 hrs. =	21° 13.1 N	Incr. Diff. 116
Corr. Table IV		+ 7 7	
True Dcl.		21° 20.8 or 21° 20′ 48″ N	

S. D. 16′. H. P. 58.7.
Corr. from Table 24 = 51′ 25″.

Mer. Alt.	24° 18′ 30″ S	True Alt.	25° 20′ 55″ S
S. D.	+ 16′		90° 00′ 00″
	24° 34′ 30″	Zenith Dist.	64° 39′ 05″ N
Dip	— 5′	True Decl.	21° 20′ 48″ N
	24° 29′ 30″	Latitude	85° 59′ 53″ N
Par. & Refr.	+ 51′ 25″		
True Alt.	25° 20′ 55″ S		

PROBLEM No. 4.

May 21, 1918. Obs. Mer. Alt. Moon's L. L. 82° 10′ 13″ S. Dip 26 ft. Chron. read 10 hrs. 18′ 26″ A. M., slow 4′ 18″.

Chron.	22 hrs. 18′ 26″
slow	4′ 18″
M. T. G. 20 —	22 hrs. 22′ 44″

Decl. 20th	22 hrs. = 8° 03.9	S Incr. Diff. 221
Corr. Table IV	+ 4 2	
True Decl.	8° 08.1 or 8° 08′ 06″ S	

S. D. 14.8. H. P. 54.2.
Corr. from Table 24 = 7′ 05″.

Mer. Alt.	82° 10′ 13″ S	True Alt.	82° 27′ 06″ S
S. D.	+ 14′ 48″		90° 00′ 00″
	82° 25′ 01″	Zenith Dist.	7° 32′ 54″ N
Dip	— 5′	True Decl.	8° 08′ 06″ S
	82° 20′ 01″	Latitude	0° 35′ 12″ S
Par. & Ref.	+ 7′ 05″		
True Alt.	82° 27′ 06″ S		

PROBLEM No. 5.

April 18, 1918. Obs. Mer. Alt. Moon's L. L. 46° 58′ 12″ N. Dip 28 ft. Chron. read 6 hrs. 18′ 16″ P. M., slow 48′ 12″.

Chron.	6 hrs. 18′ 16″
slow	+ 48′ 12″
M. T. G. 18 —	7 hrs. 06′ 28″

Decl. 18th	6 hrs. = 15° 55.8	N Decr. Diff. 185
Corr. Table IV	— 10 5	
True Decl.	15° 45.3 or 15° 45′ 18″ N	

S. D. 15.1 H. P. 55.2.
Corr. from Table 24 = 36′ 30″.

Mer. Alt.	46° 58′ 12″ N	True Alt.	47° 44′ 37″ N
S. D.	+ 15′ 06″		90° 00′ 00″
	47° 13′ 18″	Zenith Dist.	42° 15′ 23″ S
Dip	— 5′ 11″	True Decl.	15° 45′ 18″ N
	47° 08′ 07″	Latitude	26° 30′ 05″ S
Par. & Refr.	+ 36′ 30″		
True Alt.	47° 44′ 37″ N		

PROBLEM No. 6.

Dec. 6, 1918. Obs. Mer. Alt. Moon's L. L. 82° 28′ 36″ S. Dip 18 ft. Chron. read 2 hrs. 16′ 28″ A. M., fast 34′ 18″ .

Chron.	14 hrs. 16′ 28″
fast	— 34′ 18″
M. T. G. 5 —	13 hrs. 42′ 10″

Decl. 5th 12 hrs. = 20° 38.7 S Decr. Diff. 102
Corr. Table IV — 8 5

True Decl. 20° 30.2 or 20° 30′ 12″ S.

S. D. 15.3. H. P. 56.1.
Corr. from Table 24 = 7′ 02″.

Mer. Alt.	82° 28′ 36″ S	True Alt.	82° 46′ 47″ S
S. D.	+ 15′ 18″		90° 00′ 00″
	82° 43′ 54″	Zenith Dist.	7° 13′ 23″ N
Dip	— 4′ 09″	True Decl.	20° 30′ 12″ S
	82° 39′ 45″	Lat.	13° 16′ 49″ S
Par. & Refr.	+ 7′ 02″		
True Alt.	82° 46′ 47″ S		

TIME OF MOON'S MERIDIAN PASSAGE.

PROBLEM No. 1.

Jan. 28, 1918. Find Mer. Passage of Moon in Long. 84° 24 W.

Long. in time 5 hrs. 37′ 36″.

Moon's Transit	28 — 13 hrs. 31′	Diff. 41
Corr. Table IV	Wor + 9	
Meridian Passage	13 hrs. 40′ or 1 hr. 40 A. M.	

PROBLEM No. 2.

Feby. 7, 1918. Find Mer. Passage of Moon in Long. 128° 14 E.

Long. in time 8 hrs. 32′ 56″.

Moon's Transit	7 — 21 hrs. 23′	Diff. 58
Corr. Table IV	— 22′	
Mer. Passage	21 hrs. 01′ or 9 hr. 01 A. M.	

PROBLEM No. 3.

March 10, 1918. Find Mer. Passage of Moon in Lon. 178° 23 W.

Long. in time 11 hrs. 53′ 32″.

Moon's Transit	10 — 22 hrs. 50′	Diff. 54
Corr. Table IV	+ 27′	
Mer. Passage	23 hrs. 17′ or 11 hrs. 17 A. M.	

PROBLEM No. 4.

April 8, 1918. Find Meridian passage of Moon in Long. 8° 16 E.

Long. in time 33′ 04″.

Moon's Transit 8th	— 22 hrs. 21′	Diff. 55
Corr. Table IV	— 1′	
Mer Passage	22 hrs. 20′ or 10 hrs. 20′ A. M.	

PROBLEM No. 5.

June 16, 1918. Find Meridian passage of Moon in Long. 110° 18 W.

Long. in time 7 hrs. 21′ 12″.

Moon's Transit 16th	— 6 hrs. 04′	Diff. 41
Corr. Table IV	+ 12′	
Mer. Passage	6 hrs. 16′	P. M.

PROBLEM No. 6.

July 11, 1918. Find Meridian passage of Moon in Long. 156° E.

Long. in time 10 hrs. 24′.

Moon's Transit 11th	— 2 hrs. 35′	Diff. 43
Corr. Table IV	— 17′	
Mer. Passage	2 hrs. 18′	P.M.

CHAPTER XVIII.

LONGITUDE BY SUNRISE AND SUNSET OBSERVATIONS.

This problem is to find the longitude when the Sun's Upper or Lower Limb just touches the horizon at sunrise or sunset.

It is only necessary to use a pair of marine glasses for this observation, and the chronometer must be read at instant of contact with horizon.

As it is very doubtful that a proper contact with sun and horizon has been noted, this observation is not to be relied upon, but the navigator should understand it, as it is often the case that he does not get any sights during the day and the sun sets in the clear. He can then get a fairly good idea of his longitude from this problem.

Correct chronometer and find M. T. G.

Take out Declination and Equation of time for Greenwich date and time.

Find A. T. G. and Polar Distance as before.

Add together Latitude and Polar Distance.

Subtract 21′ from this sum if Lower Limb was observed.

Subtract 53′ from this sum if Upper Limb was observed.

Divide result by 2. Answer will be Half Sum.

Add 21′ to Half Sum if Lower Limb was observed.

Add 53′ to Half Sum if Upper Limb was observed.

Result will be Remainder.

From Table 44 take out following Logs:

Secant of Latitude. Rejecting 10 from Index Number.

Cosecant of Polar Distance. Rejecting 10 from Index Number.

Cosine of Half Sum.

Sine of Remainder.

Add these four logs together, and subtract 10 from Index Number.

Log Haversine that agrees with sum of logs, will be A. T. S.

If the sun was rising look from bottom of page, and date one day back.

If sun was setting look from top of page, and date same as example.

Apply A. T. S. to A. T. G. as in previous methods for longitude, and obtain the longitude of the place.

These problems in this book will be given with the longitude by D. R. and the chronometer time as it reads from the chronometer. The student must ascertain for himself whether the chronometer time is A. M. or P. M.

LONGITUDE BY SUNRISE AND SUNSET SIGHTS.

PROBLEM No. 1.

Jany. 11, 1918. Sun's L. L. at Sunset observed. Chron. read 11 hrs. 03′ 12″ which was slow on Dec. 6th 15′ 28″ and gaining 4″.7 daily. Long. by D. R. 96° East. Lat. 18° 14 North.

Chron.	23 hrs. 03′ 12″	Interval	36 days
slow	+ 15′ 28″	Daily rate	4″.7
	23 hrs. 18′ 40″		169″ = 2′ 49″
Acc. rate	— 2′ 49″		Acc. rate
M.T.G. 10 —	23 hrs. 15′ 51″		
Eq. T.	— 7′ 50″	Declination	21° 53′ 42″ S
			90° 00′ 00″
A.T.G. 10 —	23 hrs. 08′ 01″		
		Polar Dist.	111° 53′ 42″

Lat.	18° 14	Secant	.02237
Polar Dist.	111° 53′ 42″	Cosecant	.03253
	130° 07′ 42″		
	— 21′		
	2(129° 46′ 42″		
Half Sum	64° 53′ 21″	Cosine	9.62784
	+ 21′		
Remainder	65° 14′ 21″	Sine	9.95810
		Log Haversine	9.64084

A. T. S. 10 —	29 hrs. 31′ 13″
A. T. G. 10 —	23 hrs. 08′ 01″
Long. in T.	6 hrs. 23′ 12″

Long. 95° 48 East.

PROBLEM No. 2.

Feby. 23, 1918. Sun's Upper Limb at Sunset observed. Chron. read 11 hrs. 18′ 26″ which was slow on Jany. 10th 58′ 12″ and loses 7″.2 daily. Long. by D. R. 96° 50 W. Lat. 29° 28 North.

Chron.	11 hrs. 18′ 26″	Interval	44.5 days
slow	+ 58′ 12″	Daily rate	7″.2
	12 hrs. 16′ 38″		320″ = 5′ 20″
Acc. rate	+ 5′ 20″		Acc. rate
M.T.G. 23 —	12 hrs. 21′ 58″	Declination	9° 50′ 12″ S
Eq. T.	— 13′ 31″		90° 00′ 00″
A.T.G. 23 —	12 hrs. 08′ 27″	Polar Dist.	99° 50′ 12″

Lat.	29° 28	Secant	.06016
Polar Dist.	99° 50′ 12″	Cosecant	.00643
	129° 18′ 12″		
	— 53′		
	2(128° 25′ 12″		
Half Sum	64° 12′ 36″	Cosine	9.63846
	+ 53′		
Remainder	65° 05′ 36″	Sine	9.95763
		Log Haversine	9.66268

A. T. S. 23 —	5 hrs. 41′ 36″
A. T. G. 23 —	12 hrs. 08′ 27″
Long. in T.	6 hrs. 26′ 51″

Long. 96° 42′ 45″ West.

PROBLEM No. 3.

April 24, 1918. Sun's Lower Limb at Sunrise. Chron. read 0 hrs. 16′ 18″ which was slow on April 3d 18′ 02″ and gaining 4″.6 daily. Long. by D. R. 86° 15 East. Lat. 23° 10 South.

Chron.	12 hrs. 16′ 18″	Interval	20.5 days
slow	+ 18′ 02″	Daily rate	4″.6
	12 hrs. 34′ 20″		94″ = 1′ 34″
Acc. rate	— 1′ 34″		Acc rate
M.T.G. 23 —	12 hrs. 32′ 46″	Declination	12° 31′ 54″ N
Eq. T.	+ 1′ 42″		90° 00′ 00″
A.T.G. 23 —	12 hrs. 34′ 28″	Polar Dist.	102° 31′ 54″

Lat.	23° 10′	Secant	.03651
Pol. Dist.	102° 31′ 54″	Cosecant	.01047
	125° 41′ 54″		
	— 21′		
	2(125° 20′ 54″		
Half Sum	62° 40′ 27″	Cosine	9.66197
	+ 21′		
Remainder	63° 01′ 27″	Sine	9.94995
		Log Haversine	9.65890

A. T. S. 23 —	18 hrs. 20′ 13″
A. T. G. 23 —	12 hrs. 34′ 28″
Long. in T.	5 hrs. 45′ 45″

Long. 86° 26′ 15″ East.

PROBLEM No. 4.

May 6, 1918. Sun's Upper Limb at Sunrise. Chron. read 1 hr. 12′ 10″ which was slow on April 21st 3′ 18″ and losing 3″.6 daily. Long. by D. R. 105° West. Lat. 19° 18 South.

Chron.	1 hr. 12′ 10″	Interval	15 days
slow	+ 3′ 18″	Daily rate	3″.6
	1 hr. 15′ 28″		54″ Acc. rate
Acc. rate	+ 54″		
		Declination	16° 23′ 42″ N
M. T. G. 6 —	1 hr. 16′ 22″		90° 00′ 00″
Eq. T.	+ 3′ 27″		
		Polar Dist.	106° 23′ 42″
A. T. G. 6 —	1 hr. 19′ 49″		

Lat.	19° 18	Secant	.02512
Polar Dist.	106° 23′ 42″	Cosecant	.01804
	125° 41′ 42″		
	— 53′		
	2(124° 48′ 42″		
Half Sum	62° 24′ 21″	Cosine	9.66586
	+ 53′		
Remainder	63° 17′ 21″	Sine	9.95097
		Log Haversine	9.65999

A. T. S. 5 —	18 hrs. 19′ 42″
A. T. G. 5 —	25 hrs. 19′ 49″
Long. in T.	7 hrs. 00′ 07″

Long. 105° 01′ 45″ West.

PROBLEM No. 5.

June 12, 1918. Sun's Lower Limb at Sunset. Chron. read 12th 13 hrs. 15′ 16″ which was fast 13′ 14″ on May 6th and losing 6″.3 daily. Long. by D. R. 129° West. Lat. 42° 10 S.

Chron.	13 hrs. 15′ 16″	Interval	37.5 days
fast	— 13′ 14″	Daily rate	6″.3
	13 hrs. 02′ 02″		236″ = 3′ 56″
Acc. rate	+ 3′ 56″		Acc. rate
M.T.G. 12 —	13 hrs. 05′ 58″	Declination	23° 09′ 30″ N
Eq. T.	+ 25″		90° 00′ 00″
A.T.G. 12 —	13 hrs. 06′ 23″	Pol. Dist.	113° 09′ 30″

Lat.	42° 10	Secant	.13007
Polar Dist.	113° 09′ 30″	Cosecant	.03648
	155° 19′ 30″		
	— 21′		
	2(154° 58′ 30″		
Half Sum	77° 29′ 15″	Cosine	9.33591
	+ 21′		
Remainder	77° 50′ 15″	Sine	9.99013
		Log Haversine	9.49259

A. T. S. 12 —	4 hrs. 31′ 06″
A. T. G. 12 —	13 hrs. 06′ 23″
Long. in T.	8 hrs. 35′ 17″

Long. 128° 49′ 15″ West.

PROBLEM No. 6.

July 14, 1918. Sun's Upper Limb at Sunset. Chron. read 11 hrs. 12′ 18″ which was fast 6′ 36″ on June 12th and losing 3″.2 daily. Long. by D. R. 127° East. Lat. 42° 10 North.

Chron.	23 hrs. 12′ 18″	Interval	32 days
fast	— 6′ 36″	Daily rate	3″.2
	23 hrs. 05′ 42″		102″ = 1′ 42″
Acc. rate	1′ 42″		Acc. rate
M.T.G. 13 —	23 hrs. 07′ 24″	Declination	21° 46′ 54″ N
Eq. T.	— 5′ 35″		90° 00′ 00″
A.T.G. 13 —	23 hrs. 01′ 49″	Polar Dist.	68° 13′ 06″

Lat.	42° 10	Secant	.13007
Pol. Dist.	68° 13′ 06″	Cosecant	.03217
	110° 23′ 06″		
	— 53′		
	2(109° 30′ 06″		
Half Sum	54° 45′ 03″	Cosine	9.76129
	+ 53′		
Remainder	55° 38′ 03″	Sine	9.91669
		Log Haversine	9.84022

A. T. S. 13 —	31 hrs. 30′ 25″
A. T. G. 13 —	23 hrs. 01′ 49″
Long. in T.	8 hrs. 28′ 36″

Long. 127° 09 East.

PROBLEM No. 7.

Feby. 18, 1918. Sun's Lower Limb at Sunset. Chron. read 2 hrs. 16′ 28″ which was fast on Jany. 12th 13′ 28″ and gaining 4″.3 daily. Long. by D. R. 67° 35 East. Lat. 18° 21 South.

Chron.	2 hrs. 16′ 28″	Interval	37.1 days
fast	— 13′ 28″	Daily rate	4″.3
	2 hrs. 03′ 00″		159″ = 2′ 39″
Acc. rate	— 2′ 39″		Acc. rate
M.T.G. 18 —	2 hrs. 00′ 21″	Declination	11° 47′ 06″ S
Eq. T.	— 14′ 08″		90° 00′ 00″
A.T.G. 18 —	1 hr. 46′ 13″	Polar Dist.	78° 12′ 54″

Lat.	18° 21′	Secant	.02266
Pol. Dist.	78° 12′ 54″	Cosecant	.00925
	96° 33′ 54″		
	— 21′		
	2(96° 12′ 54″		
Half Sum	48° 06′ 27″	Cosine	9.82467
	+ 21′		
Remainder	48° 27′ 27″	Sine	9.87412
		Log Haversine	9.73070

A. T. S. 18 —	6 hrs. 17′ 23″
A. T. G. 18 —	1 hr. 46′ 13″
Long. in T.	4 hrs. 31′ 10″

Long. 67° 47′ 30″ East.

PROBLEM No. 8.

March 2, 1918. Sun's Upper Limb at Sunset. Chron. read 11 hrs. 16′ 28″ which was fast 28′ 28″ on Feby. 3d and losing 12″.4 daily. Long. by D. R. 71° 45 W. Lat. 16° 22 North.

Chron.	11 hrs. 16′ 28″	Interval	27.5 days
fast	— 28′ 28″	Daily rate	12″.4
	10 hrs. 48′ 00″		341″ = 5′ 41″
Acc. rate	+ 5′ 41″		Acc. rate
M.T.G. 2 —	10 hrs. 53′ 41″	Declination	7° 13′ 48″ S
Eq. T.	— 12′ 19″		90° 00′ 00″
A.T.G. 2 —	10 hrs. 41′ 22″	Polar Dist.	97° 13′ 48″

Lat.	16° 22	Secant	.01796
Pol. Dist.	97° 13′ 48″	Cosecant	.00347
	113° 35′ 48″		
	— 53′		
	2(112° 42′ 48″		
Half Sum	56° 21′ 24″	Cosine	9.74360
	+ 53′		
Remainder	57° 14′ 24″	Sine	9.92473
		Log Haversine	9.68976

A. T. S.	2 —	5 hrs. 55′ 11″
A. T. G.	2 —	10 hrs. 41′ 22″
Long. in T.		4 hrs. 46′ 11″

Long. 71° 32′ 45″ West.

PROBLEM No. 9.

Jany. 2, 1918. Sun's Upper Limb at Sunrise. Chron. read Jany. 1st 10 hrs. 15′ 28″ which was slow on Dec. 1st. 1 hr. 28′ and losing 3″.9 daily. Long. by D. R. 114° 45 East. Lat. 41° 10 North.

Chron.	10 hrs. 15′ 28″	Interval	31.5 days
slow	+ 1 hr. 28′	Daily rate	3″.9
	11 hrs. 43′ 28″		123″ = 2′ 03″
Acc. rate	+ 2′ 03″		Acc. rate
M.T.G. 1 —	11 hrs. 45′ 31″	Declination	23° 00′ 42″ S
Eq. T.	— 3′ 40″		90° 00′ 00″
A.T.G. 1 —	11 hrs. 41′ 51″	Polar Dist.	113° 00′ 42″

Lat.	41° 10′	Secant	.12332
Polar Dist.	113° 00′ 42″	Cosecant	.03603
	154° 10′ 42″		
	— 53′		
	2(153° 17′ 42″		
Half Sum	76° 38′ 51″	Cosine	9.36342
	+ 53′		
Remainder	77° 31′ 51″	Sine	9.98964
		Log Haversine	9.51241

A. T. S.	1 — 19 hrs. 21′ 45″
A. T. G.	1 — 11 hrs. 41′ 51″
Long. in T.	7 hrs. 39′ 54″

Long. 114° 58′ 30″ East.

PROBLEM No. 10.

May 12, 1918. Sun's Lower Limb at Sunrise. Chron. read 3 hrs. 12′ 02″ which was fast on April 12th 1 hr. 13′ and gaining 4″.2 daily. Long. by D. R. 132° West. Lat. 32° 16 North.

Chron.	3 hrs. 12′ 02″	Interval	30.1 days
fast	— 1 hr. 13′	Daily rate	4″.2
	1 hr. 59′ 02″		126″ = 2′ 06″
Acc. rate	— 2′ 06″		Acc. rate
M.T.G. 12 —	1 hr. 56′ 56″	Declination	18° 01′ 12″ N
Eq. T.	+ 3′ 47″		90° 00′ 00″
A.T.G. 12 —	2 hrs. 00′ 43″	Polar Dist.	71° 58′ 48″

Lat.	32° 16′	Secant	.07285
Pol. Dist.	71° 58′ 48″	Cosecant	.02183
	104° 14′ 48″		
	— 21′		
	2(103° 53′ 48″		
Half Sum	51° 56′ 54″	Cosine	9.78983
	+ 21′		
Remainder	52° 17′ 54″	Sine	9.89830
		Log Haversine	9.78281

A. T. S. 11 —	17 hrs. 10′ 49″
A. T. G. 11 —	26 hrs. 00′ 43″
Long. in T.	8 hrs. 49′ 54″

Long. 132° 28′ 30″ West.

PROBLEM No. 11.

July 4, 1918. Sun's Lower Limb at Sunset. Chron. read July 4th 12 hrs. 00′ 00″ which was fast on June 6th 12′ 18″ and gaining 9″.3 daily. Long. by D. R. 65° W. Lat. 38° 16 North.

Chron.	12 hrs. 00′ 00″	Interval	28.5 days
fast	— 12′ 18″	Daily rate	9″.3
	11 hrs. 47′ 42″		265″ = 4′ 25″
Acc. rate	— 4′ 25″		Acc. rate
M.T.G. 4 —	11 hrs. 43′ 17″	Declination	22° 53′ 36″ N
Eq. T.	— 4′ 09″		90° 00′ 00″
A.T.G. 4 —	11 hrs. 39′ 08″	Polar Dist.	67° 06′ 24″

Lat.	38° 16	Secant	.10505
Pol. Dist.	67° 06′ 24″	Cosecant	.03565
	105° 22′ 24″		
	— 21′		
	2(105° 01′ 24″		
Half Sum	52° 30′ 44″	Cosine	9.78428
	+ 21′		
Remainder	52° 51′ 44″	Sine	9.90159
		Log Haversine	9.82657

A. T. S.	4 —	7 hrs. 19′ 53″
A. T. G.	4 —	11 hrs. 39′ 08″
Long. in T.		4 hrs. 19′ 15″

Long. 64° 48′ 45″ West.

PROBLEM No. 12.

Dec. 25, 1918. Sun's Upper Limb at Sunset. Chron. read 0 hrs. 12′ 18″ which was fast on Dec. 3d 1′ 08″ and losing 3″.2 daily. Long. by D. R. 96° East. Lat. 18° 14 South.

Chron.	0 hrs. 12′ 18″	Interval	22 days
fast	— 1′ 08″	D. R.	3″.2
	0 hrs. 11′ 10″		70″. = 1′ 10″
Acc. rate	+ 1′ 10″		Acc. rate
M.T.G. 25 —	0 hrs. 12′ 20″	Declination	23° 25 S
Eq. T.	+ 7″		90° 00
A.T.G. 25 —	0 hrs. 12′ 27″	Polar Dist.	66° 35

Lat.	18° 14	Secant	.02237
Pol. Dist.	66° 35	Cosecant	.03733
	84° 49′		
	— 53′		
	2(83° 56		
Half Sum	41° 58	Cosine	9.87130
	+ 53′		
Remainder	42° 51	Sine	9.83256
		Log Haversine	9.76356

A. T. S. 25 —	6 hrs. 36′ 55″
A. T. G. 25 —	0 hrs. 12′ 27″
Long. in T.	6 hrs. 24′ 28″

Long. 96° 07 East.

CHAPTER XIX.

SUMNER'S METHOD.

This method of finding the ship's position by Sumner lines is most generally used when a ship has been running several days without observations, and the dead reckoning position is doubtful.

There are various methods used in plotting Sumner lines, but the most accurate of these, and one that can be easily proved to be correct, is the method of using two assumed latitudes.

Proceed as follows:

Take an observation of sun or star, and find the longitude of two places by working this observation with the 2 assumed latitudes (a separate calculation with each latitude).

After obtaining the two positions, place them on the chart and connect them together with a line. This will give the 1st Line of Bearing, and the ship must be somwhere on this line if observation was correct. This line will be at right angles to sun's true bearing, and can be proved by entering azimuth table and obtaining true bearing at time of observation.

After the sun has changed its bearing about 20° take another observation, and find the longitude of two places, using the same assumed latitudes that were used to work 1st observation.

Place the two positions found on chart and connect them together with a line. This will give 2d line of bearing, which can be proved by azimuth table as before.

From 1st line of bearing allow the course and distance the ship has run in the interval between the two observations and draw a line paralell to the 1st line through the position found after course and distance has been allowed. This will be known as the 1st line of bearing projected.

Where the projection of the 1st line crosses the 2d line of bearing, will be ship's position at time of 2d observation.

This problem is accurate if no mistake has been made in allowing the proper course and distance between observations, and the observed altitude of each is correct.

The assumed latitudes are generally reckoned 30 miles on each side of latitude by dead reckoning.

PROBLEM No. 1. (See illustration.)

Dec. 16, 1918. A. M. at ship. When not sure of ship's position and Obs. Alt. of Sun's L. L. read 8° 16′ 40″. Dip 31 ft. Chron. read 11 hrs. 18′ 28″ A. M. which was fast on Nov. 6th 8′ 48″ and losing 8″.2 daily. Same day later in A. M. the Obs. Alt. Sun's L. L. was 18° 16′ 40″. Chron. read 0 hrs. 43′ 28″ P. M.

Ship was assumed to be between the Latitudes of 40° and 41° N.

Ship run between observations N 56° W (true) 46 miles.

Chron.	23 hrs. 18′ 28″	Interval	40 days
fast	— 8′ 48″	Daily rate	8″.2
	23 hrs. 09′ 40″		328″ = 5′ 28″
Acc. rate	+ 5′ 28″		Acc. rate
M.T.G. 15 —	23 hrs. 15′ 08″	Declination	23° 17′ 54″ S
Eq. T.	+ 4′ 35″		90° 00′ 00″
A.T.G. 15 —	23 hrs. 19′ 43″	Polar Dist.	113° 17′ 54″

Obs. Alt.	8° 16′ 40″		
S. D.	+ 16′ 12″		
	8° 32′ 52″		
Dip	— 5′ 27″		
	8° 27′ 25″		
R. & P.	— 6′ 05″		
True Alt.	8° 21′ 20″		
Lat.	40°	Secant	.11575
Pol. Dist.	113° 17′ 54″	Cosecant	.03695
	2(161° 39′ 14″		
Half Sum	80° 49′ 37	Cosine	9.20223
True Alt.	8° 21′ 20″		
Remainder	72° 28′ 17″	Sine	9.97934
		Log Haversine	9.33427

A. T. S. 15 —	20 hrs. 18′ 30″
A. T. G. 15 —	23 hrs. 19′ 43″
Long. in T.	3 hrs. 01′ 13″

Long. 45° 18′ 15″ West.

True Alt.	8° 21′ 20″		
Lat.	41°	Secant	.12222
Pol. Dist.	113° 17′ 54″	Cosecant	.03695
	2(162° 39′ 14″		
Half Sum	81° 19′ 37″	Cosine	9.17807
True Alt.	8° 21′ 20″		
Remainder	72° 58′ 17″	Sine	9.98052
		Log Haversine	9.31776

A. T. S. 15 —	20 hrs. 23′ 02″
A. T. G. 15 —	23 hrs. 19′ 43″
Long. in T.	2 hrs. 56′ 41″

Long. 44° 10′ 15″ West.

Positions for 1st line.

Lat. 40° N. Long. 45° 18′ 15″ W.
Lat. 41° N. Long. 44° 10′ 15″ W.

2d Observation.

Chron.	0 hrs. 43′ 28″	Interval	40 days
fast	— 8′ 48″	Daily rate	8″.2
	0 hrs. 34′ 40″		328″ = 5′ 28″
Acc. rate	+ 5′ 28″		Acc. rate
M.T.G. 16 —	0 hrs. 40′ 08″	Declination	23° 18′ 10″ S
Eq. T.	+ 4′ 33″		90° 00′ 00″
A.T.G. 16 —	0 hrs. 44′ 41″	Polar Dist.	113° 18′ 10″

Obs. Alt.	18° 16′ 40″		
S. D.	+ 16′ 12″		
	18° 32′ 52″		
Dip	— 5′ 27″		
	18° 27′ 25″		
R. & P.	— 2′ 44″		
True Alt.	18° 24′ 41″		
Lat.	40°	Secant	.11575
Pol. Dist.	113° 18′ 10″	Cosecant	.03695
	2(171° 42′ 51″		
Half Sum	85° 51′ 25″	Cosine	8.85868
True Alt.	18° 24′ 41″		
Remainder	67° 26′ 44″	Sine	9.96546
		Log Haversine	8.97684

A. T. S. 15 — 21 hrs. 36′ 32″
A. T. G. 15 — 24 hrs. 44′ 41″

Long. in T. 3 hrs. 08′ 09″

Long. 47° 02′ 15″ W.

True Alt.	18° 24′ 41″		
Lat.	41°	Secant	.12222
Pol. Dist.	113° 18′ 10″	Cosecant	.03695
	2(172° 42′ 51″		
Half Sum	86° 21′ 25″	Cosine	8.80289
True Alt.	18° 24′ 41″		
Remainder	67° 56′ 44″	Sine	9.96701
		Log Haversine	8.92907

A. T. S. 15 — 21 hrs. 44′ 27″
A. T. G. 15 — 24 hrs. 44′ 41″

Long. in T. 3 hrs. 00′ 14″

Long. 45° 03′ 30″ W.

2d Line of Bearing.

Lat. 40° N. Long. 47° 02′ 15″ W.
Lat. 41° N. Long. 45° 03′ 30″ W.

CHAPTER XX.

MARCQ ST. HILAIRE METHOD OR COSINE—HAVERSINE FORMULA.

This is a new method of plotting position lines on the chart, and reduces the amount of figures used in Sumner's Method considerably. It is used entirely in the U. S. Navy.

The position of the ship by Dead Reckoning must always be used to work from, and in the case where a course and distance is given in the interval between observations, the latitude and longitude by D. R. must be found for 2d Observation before working problem.

Proceed as follows:

Correct chronometer and find M. T. G.

In case of the sun observed, proceed as follows:

Apply Equation of time to M. T. G. and find A. T. G.

Apply Longitude in time to A. T. G. as follows:

Longitude East, add.

Longitude West, subtract longitude in time from M. T. G.

Result will be Local Apparent Time.

If Local A. T. is over 12 hours, subtract it from 24 hours and result will be Sun's Hour Angle.

In case of Moon, Star or Planet proceed as follows:

Apply longitude in time to M. T. G. as before, and obtain Mean Time Ship.

Add to M. T. S. the Sun's Right Ascension from Page 2 (Nautical Almanac) and correction from table below on same page for M. T. G.

Result will be Local Siderial Time.

From L. S. T. subtract Right Ascension of body observed.

Result will be Hour Angle of Body.

In all cases proceed as follows:

Take out declination of body observed.

Correct observed altitude of body observed, and find true altitude.

From Table 45 (Bowditch) take out Log Haversine of Body's Hour Angle.

From Table 44 (Bowditch) take out Log Cosine of Latitude by D. R.

From Table 44 (Bowditch) take out Log Cosine of Declination.

Add these three logs together, and subtract 20 from Index Number.

Opposite the log Haversine corresponding to sum of logs read the Natural Haversine.

If Latitude and Declination are same name, subtract less from greater.

If Latitude and Declination are different name, add the two.

Take out the Nat. Haversine of this result, and add to it the Nat. Haversine obtained already.

Nat. Haversine corresponding to the sum of the two, will be the Zenith Distance read from top of page (table 45) in degrees, minutes and seconds.

Subtract Zenith Distance from 90°. Result will be Computed Altitude.

Under Computed altitude, put down true altitude, and subtract less from greater. Answer will be Altitude Difference or Intercept.

If the true altitude is greater than computed altitude, measure from the dead reckoning position on the line of azimuth toward the body a distance equal to the altitude difference or intercept, and draw the position line through this point at right angles to true bearing.

If true altitude is less than computed altitude measure away from body.

In using the signs, + means toward the body, — means away from body.

Pick out true bearing of body from azimuth table or line of position table, which will explain itself.

If the ship has made any change of position between observations, the true course and distance must be allowed from first to second sight, and a line drawn paralell to the first line on this course and distance crossing the second line, will be the ship's position at time of second observation.

A little practice with this method will convince the student that it is very convenient and simple.

The position lines will be on the same principle as Sumner lines, the only difference between the two being the saving in time and figures for making the calculations.

MARCQ ST. HILAIRE METHOD.

PROBLEM No. 1. (See illustration.)

Dec. 16, 1918. A. M. at ship. Ship's position by D. R. Lat. 40° 27 N. Long. 44° 40 W. Obs. Alt. Sun's L. L. 8° 16′ 40″. Chron. read 11 hrs. 18′ 28″ A. M. Ship then ran until Chron. read 0 hrs. 43′ 28″ P. M. on a course of N 56° W (true) 46 miles. Obs. Alt. of Sun's L. L. 18° 16′ 40″.

Chron. was fast of Gr. time 3′ 20″. Dip 31 ft.

Ist Observation. D. R. Position Lat. 40° 27 N. Long. 44° 40 W.

Chron.	23 hrs. 18′ 28″
fast	— 3′ 20″
M.T.G. 15 —	23 hrs. 15′ 08″
Eq. T.	+ 4′ 35″
A.T.G. 15 —	23 hrs. 19′ 43″
Long. in T. —	2 hrs. 58′ 40″
L. A. T.	20 hrs. 21′ 03″
	24 hrs.
Hour Angle	3 hrs. 38′ 57″

Decl.		23° 17′ 54″ S.
Alt.		8° 16′ 40″
Corr. Table 46	+	4′ 20″
True Alt.		8° 21′ 00″

Log Haversine 3 hrs. 38′ 57″	= 9.32498
Log Cosine Lat. 40° 27	= 9.88137
Log Cosine Decl. 23° 18	= 9.96305
Log Haversine	9.16940

Lat.	40° 27 N	9.16940 = Nat. Hav. .14771
Decl.	23° 18 S	
	63° 45 =	Nat. Havcrsine .27886
		Nat. Haversine .42657 = Z.D.

Zenith Dist.	81° 33′ 15″
	90° 00′ 00″
Computed Alt.	8° 26′ 45″
True Alt.	8° 21′
Altitude Diff.	— 5′ 45″

Azimuth S 49° 30 E.

1st Observation. D. R. Position Lat.	40° 27	N
Course N 56° W. Dist. 46 miles = D. Lat.	25′ 42″	N
2d Observation. D. R. Position Lat.	40° 52′ 42″	N

1st Obs. Long. by D. R.	44° 40 W	
	50′ 30″ W	Diff. Long.
2d Obs. Long. by D. R.	45° 30′ 30″ W	

Chron.	0 hrs. 43′ 28″		Decl. 23° 18 S
fast	— 3′ 20″	Obs. Alt.	18° 16′ 40″
M.T.G. 16 —	0 hrs. 40′ 08″	Corr	+ 7′ 45″
Eq. T.	+ 4′ 33″	True Alt.	18° 24′ 25″
A.T.G. 16 —	0 hrs. 44′ 41″		
Long. in T.	3 hrs. 02′ 02″		
L. A. T.	21 hrs. 42′ 39″		
	24 hrs.		
Hour Angle	2 hrs. 17′ 21″		

Log Haversine 2 hrs. 17′ 21″	= 8.94019
Log Cosine 40° 53	= 9.87855
Log Cosine 23° 18	= 9.96305
Log Haversine	8.78179

Lat.	40° 53 N	8.78179 = Nat. Hav. 06050
Decl.	23° 18 S	
	64° 11 =	Nat. Haversine .28225
		Nat. Haversine .34275 = Z.D.

Zenith Dist.	71° 40′ 15″
	90° 00′ 00″
Computed Alt.	18° 19′ 45″
True Alt.	18° 24′ 25″
Altitude Diff.	+ 4′ 40″

See illustration.

Azimuth S 33° E.

PROBLEM No. 2.

SIMULTANEOUS OBSERVATION OF TWO FIXED STARS.

April 16, 1918. P. M. Position by D. R. Lat. 37° 14 N. Long. 76° 04 W.

Chron. read 7 hrs. 05′ 45″ P. M. Sirius in the West. Altitude 29° 29.

Chron. read 7 hrs. 07′ 45″ P. M. Capella in the West. Altitude 50° 14.

Chron. was slow 5 hrs. 00′ 01″. Dip 41 ft.

Sirius in the West.

Chron.	7 hrs. 05′ 45″	Decl.	16° 36′ 24″ S.
slow	+ 5 hrs. 00′ 01″		
		Obs. Alt.	29° 29
M.T.G. 16	— 12 hrs. 05′ 46″	Corr.	— 8
Long. T.	— 5 hrs. 04′ 16″		
		True Alt.	29° 21
M. T. S.	7hrs. 01′ 30″		
Sun's R. A.	1 hr. 35′ 16″		
Corr. for Gr. T.	+ 1′ 59″		
L. S. T.	8 hrs. 38′ 45″		
Star's R. A.	6 hrs. 41′ 34″		
Star's H. A.	1 hr. 57′ 11″		

Log Haversine 1 hr. 57′ 11″	= 8.80582
Log Cosine 37° 14	= 9.90101
Log Cosine 16° 36	= 9.98151
Log Haversine	8.68834

Lat.	37° 14 N	8.68834 = Nat. Hav. .04879
Decl.	16° 36 S	
	53° 50 =	Nat. Haversine .20493
		Nat. Haversine .25372 = Z.D.

Zenith Dist.	60° 29′ 30″
	90° 00′ 00″
Computed Alt.	29° 30′ 30″
Tru eAlt.	29° 21
Altitude Diff.	— 9′ 30″

Azimuth S 32° W.

Capella in the West.

1st Chron. T.	7 hrs. 05′ 45″		Decl. 45° 55 N.
2d Chron. T.	7 hrs. 07′ 45″		
		Alt.	50° 14
Interval	2′	Corr.	— 7
1st L. S. T.	8 hrs. 38′ 45″		
		True	50° 07
2d L. S. T.	8 hrs. 40′ 45″		
Star's R. A.	5 hrs. 10′ 40″		
Star's H. A.	3 hrs. 30′ 05″		

Log Haversine 3 hrs. 30′ 5″	= 9.29173
Log Cosine 37° 14	= 9.90101
Log Cosine 45° 55	= 9.84242
Log Haversine	9.03516

Lat.	37° 14 N	9.03516 = Nat. Hav. .10842
Decl.	45° 55 N	
	8° 41 =	Nat. Haversine .00573
		Nat. Haversine .11415 = Z.D.
Zenith Dist.	39° 29′ 45″	
	90° 00′ 00″	
Computed Alt.	50° 30′ 15″	
True Alt.	50° 07′	
Alt. Difference	— 23′ 15″	Azimuth N 59° W.

Position of vessel: Lat. 37° 10 N. Long. 75° 33′ 15″ W.

PROBLEM No. 3.

POSITION BY OBSERVATION OF 3 FIXED STARS.

Ship stationary between observations.

May 18, 1918. P. M. Position by D. R| Lat. 40° 40 N. Long. 69° W.

Chron. read 7 hrs. 34′ 37″ P. M. Star Polaris. Altitude 39° 42.

Chron. read 7 hrs. 36′ 58″ P. M. Star Vega in the East. Altitude 16° 32.

Chron. read 7 hrs. 38′ 55″ P. M. Star Capella in the West. Altitude 22° 40.

Chron. slow 4 hrs. 59′ 27″. Dip 41 ft.

Polaris.

		Obs. Alt.	39° 42
Chron.	7 hrs. 34′ 37″	Corr.	— 7′ 26″
slow	+ 4 hrs. 59′ 27″		
		True Alt.	39° 34′ 34″
M.T.G. 18 —	12 hrs. 34′ 34″	Corr from	
Long. in T.	4 hrs. 36′	Table I +	1° 00′ 12″
M. T. S.	7 hrs. 58′ 04″	Lat.	40° 34′ 46″ N
Sun's R. A.	3 hrs. 41′ 26″		
Corr.	+ 2′ 04″		
L. S. T.	11 hrs. 41′ 33″		Azimuth 0°

Vega in the East.

1st Chron. T.	7 hrs. 34′ 37″		Decl. 38° 42 N.
2d Chron. T.	7 hrs. 36′ 58″		
		Alt.	16° 32′
Interval	2′ 21″	Corr.	— 9′ 30″
1st L. S. T.	11 hrs. 41′ 33″		
		True Alt.	16° 22′ 30″
2d L. S. T.	11 hrs. 43′ 55″		
+	24 hrs.		
	35 hrs. 43′ 55″		
Star's R. A.	18 hrs. 34′ 12″		
	17 hrs. 09′ 43″		
	24 hrs.		
Star's H. A.	6 hrs. 50′ 17″		

Log Haversine 6 hrs. 50′ 17″	= 9.78449
Log Cosine 40° 40	= 9.87996
Log Cosine 38° 42	= 9.89233
Log Haversine	9.55678

Lat.	40° 40 N	9.55678 = Nat. Hav.	.36040
Decl.	38° 42 N		
	1° 58 =	Nat. Haversine	.00029
		Nat. Haversine	36069 =Z.D.
Zenith Dist.	73° 49′ 15″		
	90° 00′ 00″		
Computed Alt.	16° 10′ 45″		
True Alt.	16° 22′ 30″		
Altitude Diff.	+ 11′ 45″		Azimuth N 53° E

Capella in the West.

1st Chron. T.	7 hrs. 34′ 37″		Decl. 45° 55 N.
3d Chron. T.	7 hrs. 38′ 55″		
		Obs. Alt.	22° 40′
Interval	4′ 18″	Corr.	— 8′ 37″
1st L. S. T.	11 hrs. 41′ 33″		
		True Alt.	22° 31′ 23″
3d L. S. T.	11 hrs. 45′ 51″		
Star's R. A.	5 hrs. 10′ 39″		
Star's H. A.	6 hrs. 35′ 12″		

Log Haversine 6 hrs. 35′ 12″	= 9.76079
Log Cosine 40° 40	= 9.87996
Log Cosine 45° 55	= 9.84242
Log Haversine	9.48317

Lat.	40° 40 N	9.48317 = Nat. Hav.	.30420
Decl.	45° 55 N		
	5° 15 =	Nat. Haversine	.00210
Zenith Dist.	67° 12′ 30″	Nat. Haversine	.30630 =Z.D.
	90° 00′ 00″		
Computed Alt.	22° 47′ 30″		
True Alt.	22° 31′ 23″		
Altitude Diff.	— 16′ 07″		Azimuth N 48° W.

Position of vessel: Lat. 40° 35′ 30″ N. Long. 68° 36′ 15″ W.

PROBLEM No. 4.

POSITION BY OBSERVATION OF FOUR FIXED STARS.

Ship stationary during interval of observations.

May 19, 1918. P. M. Ship's position by D. R. Lat. 37° 50 N. Long. 74° 00 W.

Chron. read 7 hrs. 45′ 46″. Capella in the West. Altitude 22° 08.

Chron. read 7 hrs. 47′ 00″. Vega in the East. Altitude 14° 03.

Chron. read 7 hrs. 49′ 39″. Spica in the East. Altitude 36° 19.

Chron. read 7 hrs. 51′ 16″. Procyon in the West. Altitude 25° 11.

Chron. slow 4 hrs. 59′ 24″ . Dip 41 ft.

Capella in the West.

Chron.	7 hrs. 45′ 46″		Decl. 45° 55 N.
slow	+ 4 hrs. 59′ 24″		
		Obs. Alt.	22° 08′
M.T.G. 19 —	12 hrs. 45′ 10″	Corr.	— 8′ 40″
Long. in T.	4 hrs. 56′		
		True Alt.	21° 59′ 20″
M. T. S.	7 hrs. 49′ 10″		
Sun's R. A.	3 hrs. 45′ 23″		
Corr.	+ 2′ 06″		
L. S. T.	11 hrs. 36′ 39″		
Star's R. A.	5 hrs. 10′ 39″		
Star's H. A.	6 hrs. 26′ 00″		
	12 hrs.		
For. Az.	5 hrs. 34′		

Log Haversine 6 hrs. 26′	= 9.74554
Log Cosine 37° 50	= 9.89752
Log Cosine 45° 55	= 9.84242
Log Haversine	9.48548

Lat.	37° 50 N	9.48548 = Nat. Hav. .30584
Decl.	45° 55 N	
	8° 05 =	Nat. Haversine .00497
		Nat. Haversine .31081 = Z.D.
Zenith Dist.	67° 46	
	90° 00	
Computed Alt.	22° 14′	
True Alt.	21° 59′ 20″	
Altitude Diff.	— 14′ 40″	Azimuth N 48° W.

Vega in the East.

1st Chron. T.	7 hrs. 45′ 46″		Decl. 38° 42″ N.	
2d Chron. T.	7 hrs. 47′ 00″			
			Alt.	14° 03
Interval	1′ 14″		Corr.	— 10
1st L. S. T.	11 hrs. 36′ 39″			
			True Alt.	13° 53
2d L. S. T.	11 hrs. 37′ 53″			
+	24 hrs.			
	35 hrs. 37′ 53″			
Star's R. A.	18 hrs. 34′ 12″			
	17 hrs. 03′ 41″			
	24 hrs.			
Star's H. A.	6 hrs. 56′ 19″			
For Az.	5 hrs. 03′ 41″			

Log Haversine 6 hrs. 56′ 19	= 9.79353
Log Cosine 37° 50	= 9.89752
Log Cosine 38° 42	= 9.89233
Log Haversine	9.58338

Lat.	37° 50 N	9.58338 = Nat. Hav. .38317
Decl.	38° 42 N	
	0° 52 =	Nat. Haversine .00006
		Nat. Haversine .38323 = Z.D.

Zenith Dist.	76° 29′ 45″	
	90° 00′ 00″	
Computed Alt.	13° 30′ 15″	
True Alt.	13° 53′	
Altitude Diff.	+ 22′ 45″	Azimuth N 51° 30 E.

Spica in the East.

1st Chron. T.	7 hrs. 45′ 46″		Decl. 10° 44 S.
3d Chron. T.	7 hrs. 49′ 39″		
		Obs. Alt.	36° 19′
Interval	3′ 53″	Corr.	— 7′ 35″
1st L. S. T.	11 hrs. 36′ 39″		
		True Alt.	36° 11′ 25″
3d L. S. T.	11 hrs. 40′ 32″		
	+ 24 hrs.		
	35 hrs. 40′ 32″		
Star's R. A.	13 hrs. 20′ 55″		
	22 hrs. 19′ 37″		
	24 hrs.		
Star's H. A.	1 hr. 40′ 23″		

Log Haversine 1 hr. 40′ 23″	= 8:67394
Log Cosine 37° 50	= 9.89752
Log Cosine 10° 44	= 9.99233
Log Haversine	8.56379

Lat.	37° 50 N	8.56379 = Nat. Hav. .03663
Decl.	10° 44 S	
	48° 34 =	Nat. Haversine .16913
		Nat Haversine .20576 = Z.D.

Zenith Dist.	53° 57′	
	90° 00′	
Computed Alt.	36° 03′	
True Alt.	36° 11′ 25″	
Altitude Diff.	+ 8′ 25″	Azimuth S 31° E.

Procyon in the West.

1st Chron. T.	7 hrs. 45′ 46″		Decl. 5° 26 N.
4th Chron. T.	7 hrs. 51′ 16″		
		Obs. Alt.	25° 11′
Interval	5′ 30″	Corr.	— 8′ 20″
1st L. S. T.	11 hrs. 36′ 39″		
		True Alt.	25° 02′ 40″
4th L. S. T.	11 hrs. 42′ 09″		
Star's R. A.	7 hrs. 35′ 02″		
Star's H. A.	4 hrs. 07′ 07″		

Log Haversine 4 hrs. 07′ 07″	= 9.42089
Log Cosine 37° 50	= 9.89752
Log Cosine 5° 26	= 9.99804
Log Haversine	9.31645

Lat.	37° 50 N	9.31645 = Nat. Hav. .20723
Decl.	5° 26 N	
	32° 24 =	Nat. Haversine .07784
		Nat. Haversine .28507 = Z.D.
Zenith Dist.	64° 32′ 15″	
	90° 00′ 00″	
Computed Alt.	25° 27′ 45″	
True Alt.	25° 02′ 40″	
Altitude Diff.	— 25′ 05″	Azimuth S 76° W.

Position of vessel: Lat. 37° 55′ 15″ N. Long. 73° 28′ 45″ W.

PROBLEM No. 5.

TWO OBSERVED ALTITUDES SUN'S L. L.

Oct. 18, 1918. A. M. at ship. Position by D. R. Lat. 36° 35 N. Long. 70° 35 W.

Chron. read 11 hrs. 59′ 16″. Altitude 11° 48′ 16″.

Chron. read 1 hr. 59′ 16″. Altitude 32° 14′ 30″.

Course between sights S 28° E (true) 31 miles.

Chron. slow 3′ 00″. Dip 30 ft.

Chron.	23 hrs. 59′ 16″		
slow	+ 3′		Decl. 9° 25′ 30″ S.
M.T.G. 18 —	0 hrs. 02′ 16″		
Long. in T.	4 hrs. 42′ 20″		
M. T. S.	19 hrs. 19′ 56″		
Eq. T.	+ 14′ 39″		
A. T. S.	19 hrs. 34′ 35″	Obs. Alt.	11° 48′ 16″
	24 hrs.	Corr.	+ 6′ 15″
Hour Angle	4 hrs. 25′ 25″	True Alt.	11° 54′ 31″

Log Haversine 4 hrs. 25′ 25″	= 9.47634
Log Cosine 36° 35	= 9.90471
Log Cosine 9° 25′ 30″	= 9.99410
Log Haversine	9.37515

Lat. 36° 35′ 00″ N		9.37515 = Nat. Hav. .23721
Dec. 9° 25′ 30″ S		
46° 00′ 30″ =		Nat. Haversine .15269
		Nat. Haversine .38990 = Z.D.
Zenith Dist.	77° 16′ 45″	
	90° 00′ 00″	
Computed Alt.	12° 43′ 15″	
True Alt.	11° 54′ 31″	
Altitude Diff.	— 48′ 44″	Azimuth S 67° E.

Ist Obs. D. R. Pos.	Lat. 36° 35′ 00″ N	Lon. 70° 35′ W
Diff. Lat.	27′ 24″ S	Dif. Lon. 18′ E
2d Obs. D. R. Pos.	Lat. 36° 07′ 36″ N	Lon. 70° 17′ W

Chron.	1 hr. 59′ 16″		Decl. 9° 27′ 15″ S.
slow	+ 3′		
		Obs. Alt.	32° 14′ 30″
M.T.G. 18	— 2 hr. 02′ 16″	Corr.	+ 9′ 14″
Long. T.	— 4 hr. 41′ 08″		
		True Alt.	32° 23′ 44″
M. T. S.	21 hrs. 21′ 08″		
Eq. T.	+ 14′ 40″		
A. T. S.	21 hr. 35′ 48″		
	24 hr.		
Sun's H. A.	2 hr. 24′ 12″		

Log Haversine 2 hrs. 24′ 12″	= 8.98113
Log Cosine 36° 07′ 30″	= 9.90726
Log Cosine 9° 27	= 9.99407
Log Haversine	8.88246

Lat. 36° 07′ 30″ N	8.88246 = Nat. Hav. .07628
Dec. 9° 27′ 15″ S	
45° 34′ 45″ =	Nat. Haversine .15004
	Nat. Haversine .22632 = Z.D.

Zenith Dist.	56° 48′ 45″
	90° 00′ 00″
Computed Alt.	33° 11′ 15″
True Alt.	32° 23′ 44″
Altitude Diff.	— 47′ 31″

Azimuth S 43° 30 E.

Position of vessel: Lat. 36° 33′ 30″ N. Long. 71° 08′ 30″ W.

PROBLEM No. 6.

POSITION BY SIMULTANEOUS OBSERVATIONS OF TWO FIXED STARS.

Dec. 6, 1918. Position by D. R. 49° 30 N. Long. 14° 00 W.

Chron. read 7 hrs. 30′ 20″. Regulus in the West. Altitude 48° 41′ 30″.

Chron. read 7 hrs. 31′ 43″ . Arcturus in the East. Altitude 46° 32′ 30.

Chron. correct. Dip 26 ft.

Regulus in the West.

M.T.G. 5 —	19 hrs. 30′ 20″		Decl. 12° 21′ 42″ N.
Long. in T.	0 hrs. 56′		
		Obs. Alt.	48° 41′ 30″
M. T. S.	18 hrs. 34′ 20″	Corr.	— 5′ 51″
Sun's R. A.	16 hrs. 53′ 54″		
Corr.	+ 3′ 12″	True Alt.	48° 35′ 39″
	35 hrs. 31′ 26″		
—	24 hrs.		
L. S. T.	11 hrs. 31′ 26″		
Star's R. A.	10 hrs. 04′ 04″		
Star's H. A.	1 hr. 27′ 22″		

Log Haversine 1 hr. 27′ 22″	= 8.55500
Log Cosine 49° 30	= 9.81254
Log Cosine 12° 22	= 9.98980
Log Haversine	8.35734

Lat.	49° 30 N	8.35734 = Nat. Hav. .02277
Decl.	12° 22 N	
	37° 08 =	Nat. Haversine .10138
		Nat. Haversine .12415 = Z.D.

Zenith Dist.	41° 15′ 45″	
	90° 00′ 00″	
Computed Alt.	48° 44′ 15″	
True Alt.	48° 35′ 39″	Azimuth S 33° 30 W.
Altitude Diff.	— 8′ 36″	

Arcturus in the East.

1st Chron. T.	7 hrs. 30′ 20″	Decl.	19° 36′ 12″ N.
2d Chron. T.	7 hrs. 31′ 43″		
Interval	1′ 23″		
1st L. S. T.	11 hrs. 31′ 26″		
2d L. S. T.	11 hrs. 32′ 49″		
+	24 hrs.		
	35 hrs. 32′ 49″		
Star's R. A.	14 hrs. 11′ 57″		
	21 hrs. 20′ 52″	Obs. Alt.	46° 32′ 30″
	24 hrs.	Corr.	— 5′ 50″
Star's H. A.	2 hrs. 39′ 08″	True Alt.	46° 26′ 40″

Log Haversine 2 hrs. 39′ 08″	= 9.06358
Log Cosine 49° 30	= 9.81254
Log Cosine 19° 36	= 9.97408
Log Haversine	8.85020

Lat.	49° 30 N	8.85020 = Nat. Hav. .07083
Decl.	19° 36 N	
	29° 54 =	Nat. Haversine .06655
		Nat. Haversine .13738 = Z.D.
Zenith Dist.	43° 30′ 45″	
	90° 00′ 00″	
Computed Alt.	46° 29′ 15″	
True Alt.	46° 26′ 40″	
Altitude Diff.	— 2′ 35″	Azimuth S 61° E.

Position of vessel: Lat. 49° 39 N. Long. 13° 57 W.

CHAPTER XXI.

TIME OF HIGH AND LOW WATER.

This problem is to find the time of High and Low Water at any given port.

The astronomical date must be thoroughly understood in this example, and with careful watching of dates and a little practice it is very simple.

From Appendix IV (Bowditch) take out approximate longitude of place given, and Lunar Interval for High and Low Water.

From Page 76-77 (Nautical Almanac) take out Moon's Transit for date of example, and the difference between it and the transit for next date.

From Table 11 (Bowditch) with difference of transit at top of page, and approximate longitude on side, take out correction given and apply it to Moon's Transit by rule given in Table 11.

Result will be Moon's Upper Transit.

Add to Moon's Upper Transit the Lunar Interval for High Water. Result will be time of High Water in astronomical time.

To convert this into civil time:

If time is more than 12 hours, the astronomical date is the same as the date of example. We then subtract 12 hours from it, and the civil date will be date after example. By subtracting the Moon's difference of transit from this result, will give civil time on date of example, which will be the time of High Water required in A. M.

If the time found after adding Upper Transit and Lunar Interval was less than 12 hours, the astronomical date will be same as example, and the civil date will be the same P. M.

To find the time of Low Water.

Add to Moon's Upper Transit the Lunar Interval for Low Water. The same rule as before will hold good for finding time of Low Water.

As the difference between the morning and evening tides is half the Moon's change of transit for that date. Proceed as follows:

If time for High or Low Water was found for A. M., add one half the difference of transit to it, and the result will be P. M. time of High or Low Water.

If time found was P. M., subtract one half the difference of transit from it, and the result will be A. M. time of High or Low Water.

PROBLEM No. 1.

Jany. 18, 1918. Find time of High and Low Water A. M. and P. M. at Montauk Point, N. Y.

Approx. Long. 72° W. Lunar Inter. H. W. 8 hrs. 20′. Lunar Inter. L. W. 2 hrs. 3′.

Difference of transit 51′.

Moon's Trans. 18th	5 hrs. 02′	
Corr. Table 11	+ 10′	
Moon's Upper Transit	5 hrs. 12′	
Lun. Int. H. W.	8 hrs. 20′	
High Water Jan. 18th	13 hrs. 32′	
	— 12 hrs.	
High Water Jan. 19th	1 hr. 32′	A. M.
Diff. of Transit	— 51′	
High Water Jan. 18th	0 hrs. 41′	A. M.
One Half Diff. Trans.	+ 25′	
High Water, Jan. 18th	1 hr. 06′	P. M.
Moon's U. T.	5 hrs. 12′	
Lun. Int. L. W.	2 hrs. 03′	
Low Water 18th	7 hrs. 15′	P. M.
One Half change	— 25′	
Low Water 18th	6 hrs. 50′	A. M.

PROBLEM No. 2.

July 19, 1918. Find time of High and Low Water A. M. and P. M. at New York Navy Yard, N. Y.

Approx. Long. 74° W. L. I. H. W. 8 hrs. 44′ L. I. L. W. 2 hrs. 49′.

Difference of transit 51′.

Moon's Transit 19th	8 hrs. 31′	
Corr. Table 11	+ 10′	
Upper Transit	8 hrs. 41′	
Lun. Int. H. W.	8 hrs.44′	
High Water July 19th	17 hrs. 25′	
Diff. of Transit	— 51′	
High Water July 18th	16 hrs. 34′	
	— 12 hrs.	
High Water July 19th	4 hrs. 34′	A. M.
One Half change of Trans.	+ 25′	
High Water July 19th	4 hrs. 59′	P. M.
Upper Trans.	8 hrs. 41′	
L. I. L. W.	2 hrs. 49′	
Low Water 19th	11 hrs. 30′	P. M.
One Half change	— 25′	
Low Water 19th	11 hrs. 05′	A. M.

PROBLEM No. 3.

Sept. 13, 1918. Find time of High and Low Water A. M. and P. M. at Aden, Arabia.

Approx. Long. 45° East. L. I. H. W. 7 hrs. 49′. L. I. L. W. 1 hr. 41′.

	Difference of Transit 52′.	
Moon's Trans. 13th	5 hrs. 56′	
Corr. Table 11	— 6′	
Upper Trans.	5 hrs. 50′	
L. I. H. W.	7 hrs. 49′	
High Water Sept. 13th	13 hrs. 39′	
	— 12 hrs.	
High Water Sept. 14th	1 hr. 39′	A. M.
Diff. of Transit	— 52′	
High Water Sept. 13th	0 hrs. 47′	A. M.
One Half Change of Trans.	+ 26′	
High Water Sept. 13th	1 hr. 13′	P. M.
Upper Transit	5 hrs. 50′	
L. I. L. W.	1 hr. 41′	
Low Water 13th	7 hrs. 31′	P. M.
One Half Change	— 26′	
Low Water 13th	7 hrs. 05′	A. M.

PROBLEM No. 4.

Feby. 17, 1918. Find time of High and Low Water A. M. and P. M. at Valparaiso, Chili.

Approx. Long. 72° W. L. I. H. W. 9 hrs. 37′. L. I. L. W. 3 hrs. 26′.

	Change of Transit 56′.	
Moon's Trans. 17th	5 hrs. 38′	
Corr. Table 11	+ 11′	
Upper Trans.	5 hrs. 49′	
L. I. H. W.	9 hrs. 37′	
High Water Feby. 17th	15 hrs. 26′	
	— 12 hrs.	
High Water Feb. 18th	3 hrs. 26′	A. M.
Change of Trans.	— 56′	
High Water Feby 17th	2 hrs. 30′	A. M.
One Half Change of Trans.	+ 28′	
High Water Feby. 17th	2 hrs. 58′	P. M.
Upper Transit	5 hrs. 49′	
L. I. L. W.	3 hrs. 26′	
Low Water 17th	9 hrs. 15′	P. M.
One Half Change	— 28′	
Low Water 17th	8 hrs. 47′	A. M.

PROBLEM No. 5.

Aug. 26, 1918. Find time of High and Low Water A. M. and P. M. at Enderbury Island, Phoenix Islands, Islands of the Pacific.

Approx. Long. 171° W. L. I. H. W. 5 hrs. 00′. L. I. L. W. 11 hrs. 15′.

	Change of Transit 56′.	
Moon's Trans. 26th	16 hrs. 15′	
Corr. Table 11	+ 26′	
Upper Trans.	16 hrs. 41′	
L. I. H. W.	5 hrs. 00′	
High Water Aug. 26th	21 hrs. 41′	
	— 12 hrs.	
High Water Aug. 27th	9 hrs. 41′	A. M.
Change of Trans.	— 56′	
High Water Aug. 26th	8 hrs. 45′	A. M.
One Half Change Trans.	+ 28′	
High Water Aug. 26th	9 hrs. 13′	P. M.
Upper Trans.	16 hrs. 41′	
L. I. L. W.	11 hrs. 15′	
	27 hrs. 56′	
	— 24 hrs.	
Low Water Aug. 26th	3 hrs. 56′	P. M.
One Half Change of Trans.	— 28′	
Low Water Aug. 26th	3 hrs. 28′	A. M.

PROBLEM No. 6.

July 8, 1918. Find time of High and Low Water A. M. and P. M. at New Bedford, Mass.

Approx. Long. 71° W. L. I. H. W. 7 hrs. 57′. L. I. L. W. 1 hr. 18′.

	Change of Transit 54′.	
Moon's Trans. 8th	0 hrs. 12′	
Corr. Table 11	+ 10′	
Upper Trans.	0 hrs. 22′	
L. I. H. W.	7 hrs. 57′	
High Water July 8th	8 hrs. 19′	P. M.
One Half Change of Trans.	— 27′	
High Water July 8th	7 hrs. 52′	A. M.
Upper Transit	0 hrs. 22′	
L. I. L. W.	1 hr. 18′	
Low Water July 8th	1 hr. 40′	P. M.
One Half Change of Trans.	— 27′	
Low Water July 8th	1 hr. 13′	A. M.

PROBLEM No. 7.

Dec. 19, 1918. Find time of High Water and Low Water A. M. and P. M. at Vardo, Norway.

Approx. Long. 31° E. L. I. H. W. 5 hrs. 40′. L. I. L. W. 11 hrs. 57′.

	Change of Transit 55′.	
Moon's Trans. 19th	14 hrs. 02′	
Corr. Table 11	— 5′	
Upper Transit	13 hrs. 57′	
L. I. H. W.	5 hrs. 40′	
High Water Dec. 19th	19 hrs. 37′	
	— 12 hrs.	
High Water Dec. 20th	7 hrs. 37′	A. M.
Change of Transit	— 55′	
High Water Dec. 19th	6 hrs. 42′	A. M.
One Half Change of Trans.	+ 27′	
High Water Dec. 19th	7 hrs. 09′	P. M.
Upper Transit	13 hrs. 57′	
L. I. L. W.	11 hrs. 57′	
	25 hrs. 54′	
	— 24 hrs.	
Low Water Dec. 19th	1 hr. 54′	P. M.
One Half Change of Trans.	— 27′	
Low Water Dec. 19th	1 hr. 27′	A. M.

PROBLEM No. 8.

Feby. 4, 1918. Find time of High and Low Water A. M. and P. M. at Calais, Maine.

Approx. Long. 67° W. L. I. H. W. 11 hrs. 36′. L. I. L. W. 5 hrs. 40′.

	Change of Transit 49′.	
Moon's Trans. 4th	18 hrs. 35′	
Corr Table 11	+ 9′	
Upper Transit	18 hrs. 44′	
L. I. H. W.	11 hrs. 36′	
	30 hrs. 20′	
	— 24 hrs.	
High Water Feby. 4th	6 hrs. 20′	P. M.
One Half Change of Transit	— 24′	
High Water Feby. 4th	5 hrs. 56′	A. M.
Upper Transit	18 hrs. 44′	
L. I. L. W.	5 hrs. 40′	
	24 hrs. 24′	
	— 24 hrs.	
Low Water Feb. 4th	0 hrs. 24′	P. M.
One Half Change of Transit	— 24′	
Low Water Feb. 4th	Midnight	

PROBLEM No. 9.

May 4, 1918. Find time of High and Low Water A. M. and P. M. at Christiania, Norway.

Approx. Long. 11° E. L. I. H. W. 5 hrs. 22′. L. I. L. W. 10 hrs. 37′.

	Change of Transit 51′.	
Moon's Trans 4th	19 hrs. 19′	
Corr. Table 11	— 1′	
Upper Transit	19 hrs. 18′	
L. I. H. W.	5 hrs. 22′	
	24 hrs. 40′	
	— 24 hrs.	
High Water May 4th	0 hrs. 40′	P. M.
One Half Change of Trans.	— 25′	
High Water May 4th	0 hrs. 15′	A. M.
Upper Transit	19 hrs. 18′	
L. I. L. W.	10 hrs. 37′	
	29 hrs. 55′	
	— 24 hrs.	
Low Water May 4th	5 hrs. 55′	P. M.
One Half Change of Trans.	— 25′	
Low Water May 4th	5 hrs. 30′	A. M.

PROBLEM No. 10.

Jany. 10, 1918. Find time of High and Low Water A. M. and P. M. at Pernambuco, Picao Lighthouse, Brazil.

Approx. Long. 35° W. L. I. H. W. 4 hrs. 33′. L. I. L. W. 10 hrs. 50′.

	Change of Transit 59′.	
Moon's Trans. 10th	22 hrs. 43′	
Corr. Table 11	+ 6′	
Upper Transit	22 hrs. 49′	
L. I. H. W.	4 hrs. 33′	
	27 hrs. 22′	
	— 24 hrs.	
High Water Jan. 10th	3 hrs. 22′	P. M.
On Half Change of Trans.	— 29′	
High Water Jan. 10th	2 hrs. 53′	A. M.
Upper Transit	22 hrs. 49′	
L. I. L. W.	10 hrs. 50′	
	33 hrs. 39′	
	— 24 hrs.	
Low Water Jan. 10th	9 hrs. 39′	P. M.
One Half Change of Trans.	— 29′	
Low Water Jan. 10th	9 hrs. 10′	A. M.

PROBLEM No. 11.

March 5, 1918. Find time of High and Low Water A. M. and P. M. at Hilo, Kanaha Point Light, Hawaiian Islands.

Approx. Long. 155° W. L. I. H. W. 3 hrs. 09′. L. I. L. W. 9 hrs. 06′.

	Change of Transit 53′.	
Moon's Trans. 5th	18 hrs. 13′	
Corr. Table 11	+ 22′	
Upper Transit	18 hrs. 35′	
L. I. H. W.	3 hrs. 09′	
High Water Mar. 5th	21 hrs. 44′	
	— 12 hrs.	
High Water March 6th	9 hrs. 44′	A. M.
Change of Transit	— 53′	
High Water Mar. 5th	8 hrs. 51′	A. M.
One Half Change of Trans.	+ 26′	
High Water Mar. 5th	9 hrs. 17′	P. M.
Upper Transit	18 hrs. 35′	
L. I. L. W.	9 hrs. 06′	
	27 hrs. 41′	
	— 24 hrs.	
Low Water Mar. 5th	3 hrs. 41′,	P. M.
One Half Change of Transit	— 26′	
Low Water March 5th	3 hrs. 15′	A. M.

PROBLEM No. 12.

Oct. 26, 1918. Find time of High and Low Water A. M. and P. M. at Osaka, Fort Temposan Light, Japan.

Approx. Long. 135° E. L. I. H. W. 7 hrs. 30′. L. I. L. W. 1 hr. 25′.

	Change of Transit 49′.	
Moon's Trans. 26th	18 hrs. 23′	
Corr. Table 11	— 18′	
Upper Transit	18 hrs. 05′	
L. I. H. W.	7 hrs. 30′	
	25 hrs. 35′	
	— 24 hrs.	
High Water Oct. 26th	1 hr. 35′	P. M.
One Half of Trans.	— 24′	
High Water Oct. 26th	1 hr. 11′	A. M.
Upper Transit	18 hrs. 05′	
L. I. L. W.	1 hr. 25′	
Low Water Oct. 26th	19 hrs. 30′	
	— 12 hrs.	
Low Water Oct. 27th	7 hrs. 30′	A. M.
Change of Transit	— 49′	
Low Water Oct. 26th	6 hrs. 41′	A. M.
One Half Change of Trans.	+ 24′	
Low Water Oct. 26th	7 hrs. 05′	P. M.

INDEX

EXPLANATION OF ILLUSTRATION SHOWING METHOD OF PLOTTING ONE OBSERVATION OF SUN OR STAR ON A MERCATOR CHART.

This method is the most practical and simple that can be used on board of a ship, and is strongly recommended to the student of navigation.

The idea of the method is to find the longitude when an error in latitude has been made at the time of observation.

When the sun is on the prime vertical an error in latitude will have no effect on the longitude, as the suns bearing will then be true East or West, and the line of bearing at right angles to this or 90° away, will be North and South. At all other times an error of latitude used in an example for longitude, will make a difference in the longitude found.

To lay off on chart proceed as follows:

Take observation of sun or star, using the latitude by D R to work the observation with.

After obtaining this position, place it on the chart.

Enter Azimuth Tables and take out true bearing of body observed, using Apparent Time Ship for Sun, Hour Angle for Star.

Draw a line through the position already placed on chart at right angles to true bearing or 90° from it.

This will give the line of bearing, and the ship will be on this line somewhere if no error in altitude has been made.

Now when we obtain the latitude at noon, knowing the course and distance the ship has sailed between sight and noon, we find the correct latitude we were in at time of observation by working the latitude back to sight, using the difference of latitude obtained from Table 2 for the course and distance.

We then take a pair of dividers and obtain the length of the correct latitude on the side of the chart.

Where the dividers meet the line of bearing, keeping one point of dividers on paralell of latitude used, will be the ships correct position at time of sight.

Allowing the difference of longitude found from course and distance between sight and noon, to the longitude found on line of bearing, will give the ships noon position.

This method avoids the working of the sight over again, after the correct latitude has been found.

The following examples will illustrate the change in longitude for an error in latitude.

By taking a pair of dividers on the line in Lat. 50° 40 N the longitude will be found to be 166° 31 E.

In Lat. 50° 20 N the longitude will be 166° 07′ 45″ E.

This will illustrate the amount an error in latitude will effect the longitude on this bearing, and also the method of obtaining the longitude at time of observation with correct latitude.

EXPLANATION OF ILLUSTRATION SHOWING METHOD OF PLOTTING SUMNER LINES ON MERCATOR CHART.

The 1st line of bearing is the line drawn between the two positions found by first altitude, and is at right angles to Suns True bearing.

Example: Suns true bearing N 130° 30 E—90° equals N 40° 30 E, which is the angle of the first line.

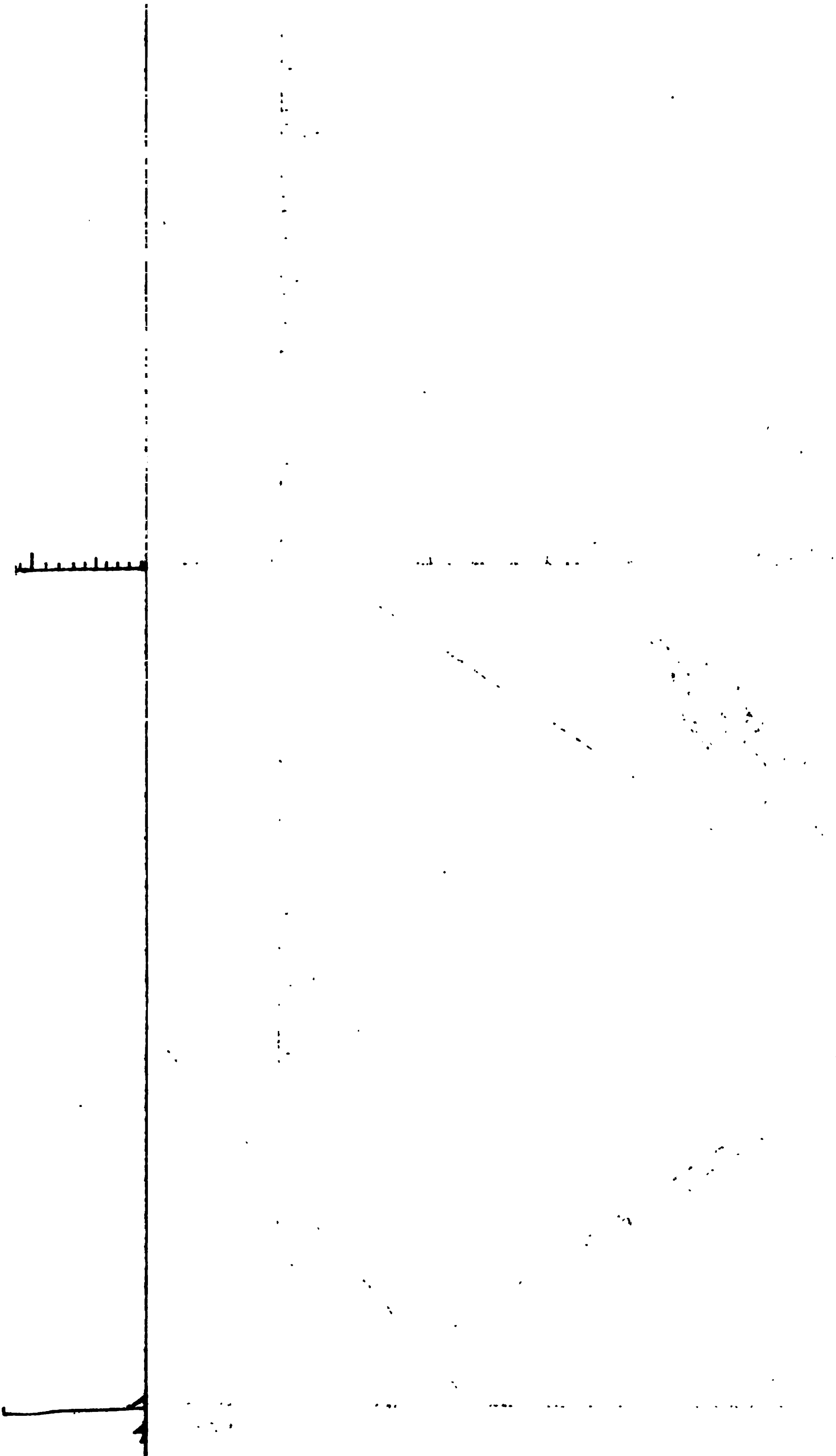
Course N 56° W (true) distance 46 miles is the line drawn allowing for the course and distance run between 1st and 2d observations.

The 1st line of bearing projected is the line drawn paralell to 1st line of bearing allowing for the course and distance.

2d Line of Bearing is the line drawn between the two positions found by 2d altitude, and is at right angles to suns true bearing.

Example: Suns true bearing N 146° E—90° equals N 56° E which is the angle of 2d line.

Where the 2d line crosses the projection of 1st line will be ships position at 2d observation.



EXPLANATION OF ILLUSTRATION SHOWING METHOD OF PLOTTING POSITION LINES ON MERCATOR CHART BY MARCQ ST. HILAIRE METHOD.

The Dead Reckoning position for 1st observation is placed on chart.

A line representing the body's true bearing is drawn through this dead reckoning position.

The Altitude difference is measured from this position towards or away from the body.

In this illustration the Altitude Difference is—5′ 45″. Or 5¾ miles on line of bearing away from the body. As the sun was in the East in A. M., this would be allowed to the westward.

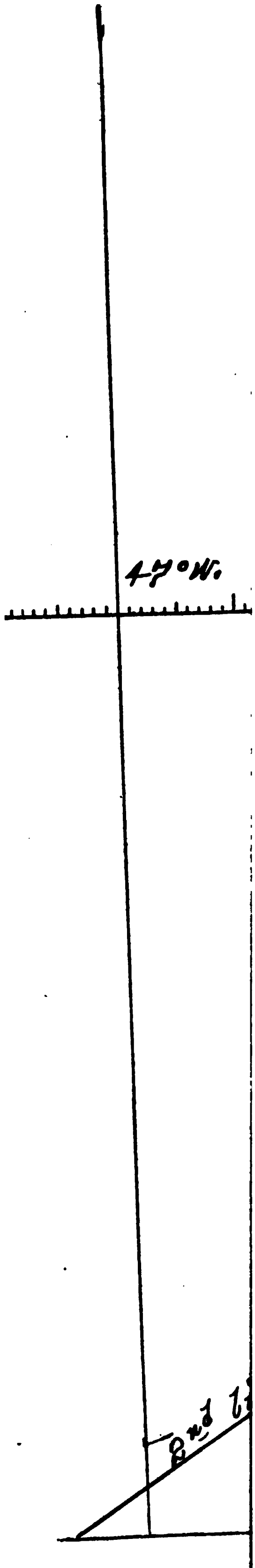
The 1st line of bearing is drawn at right angles or 90°, to this bearing.

The course and distance is allowed between observations same as in Sumners Method, and a line drawn paralell to 1st line on this course and distance.

The 2d Dead Reckoning position is then placed on chart, and a line representing the true bearing drawn through it.

In this case the Altitude Difference is +4′ 40″. which means toward the body on the line of bearing.

The 2d line is then drawn at right angles to true bearing through this position, and where the 2d line crosses the projection of 1st line will be ships position at 2d observaton.


47°W.